Spatial Information Systems: An Introduction

By Michael Kennedy
With Charles R. Meyers

URBAN STUDIES CENTER

A Publication of The Urban
Studies Center
University of Louisville

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PREFACE

This book began as a draft of a "guidebook for the development of state programs" in the area of geographic information processing. It was commissioned by the Office of Land Use and Water Planning of the U.S. Department of the Interior. The Director of that Office, Lance Marston, wanted a work that would be a comprehensive overview of the subject but which would make for understandable, even enjoyable, reading on the part of state decision makers from the highest level down.

For many reasons--the demise of the Office of Land Use and Water Planning after the failure of the Land Use Policy and Technical Assistance Act not the least of them--this work is not appearing under U.S. Government auspices. That apparent disadvantage turns out to have a positive effect. The authors had the advantage of having their material reviewed by many, both outside the government and within, but, in the final version, had complete control over the contents and the ways of expressing concepts and ideas.

The reader is warned that "federalese is not spoken within." It is the authors' conviction that while documents such as this may be written for a state or a department or the general public, it is clear that states, departments and the general public, per se, do not read. A *person* reads! We have some information to convey; within our ability, we do it in the most straightforward and interesting way for that person.

There are many other documents which contain much of the information herein presented on the subject of spatial information systems and some which contain a great deal more. In addition to those documents referenced in this work, readers may want to study the material on "Critical Areas" and "Information/Data Handling" soon to be available from the Resources and Land Investigation (RALI) program of the U.S. Geological Survey, Department of the Interior, Washington, D.C. 20240. A list of these documents and others appears in this book after the References.

About the Authors:

Michael Kennedy is a consultant to the Urban Studies Center and an associate professor at the University of Kentucky College of Architecture. His special area of concern is computer applications to environmental design. In addition to the new work on spatial information systems and a related report entitled *Avoiding System Failure,* he is the author of the computer programming text, *Ten Statement Fortran plus Fortran IV* (second edition), and *Structured PL Zero Plus PL/One* (Prentice Hall). He also compiled the *Proceedings of the Kentucky Workshop on Computer Applications to Environmental Design.*

Charles R. Meyers is staff specialist in the policy division of the U.S. Water Resources Council. Prior to assuming that position he was with the U.S. Department of Interior's Office of Land Use and Water Planning. There he served as the chief of technical services and was involved with projects designed to provide information to the states on the areas of critical involvement, concern and data handling for land-use planning.

Those concerned with the development of spatial information systems will also be interested in another publication available at the Urban Studies Center entitled *Avoiding System Failure: Approaches to Integrity and Utility.* This analytical work is especially oriented to the development of automated spatial information systems by state governments. It was written by Professor Kennedy and Charles Guinn, director of the Bureau of Policy Analysis and Planning for the New York State Energy Office, who also was instrumental in the establishment of the Land Use and Natural Resources (LUNR) Geographic Information System for the State of New York.

Avoiding System Failure: Approaches to Integrity and Utility is available at $3.00 per copy. Additional copies of *Spatial Information Systems: An Introduction* are available at $5.50 per copy.

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INTRODUCTION

The 70's may be remembered as the time in which the majority of Americans came to the understanding that the resources available to this country were limited--not just in theory but in actuality. And the early 70's may well be recorded as the peak standard of living for the century. We see the end, at the present rate of consumption, of many of our non-renewable resources; we understand now that we have used land and water in wasteful and counterproductive ways; and we are faced with the prospect of cleaning up the results of our careless living and operating in the future on a reduced and more cautious basis.

It follows that we must begin to make better decisions about development, resource allocation, land use, and protection of the environment. To deal with any of these issues singly is a monumental task. Dealing with all of them and their interrelationships, to understate the case, will require new tools and techniques--in addition to the new attitudes necessary.

It is the thesis of this work that a tool of prime importance is a system which produces not only information about those entities which are part of our present and future physical world, but also the *locations* of those entities. The combination of people, methodologies, equipment and infrastructure which provides such information we call a geographic information system or spatial information system.

Much of the material in this work is oriented toward the idea that spatial information systems will be developed by governmental organizations no smaller than states. We divide our discussion into six sections, to wit:

Part A--DECISIONMAKING AND ITS UNDERPINNINGS: DATA AND INFORMATION
Introduces the reader to the concepts of spatial data and the types of information systems which process these data. This section relates the use of spatial information systems to the process of decisionmaking.

Part B--POTENTIAL USES FOR A SPATIAL INFORMATION SYSTEM
Provides a context for spatial information systems in terms of decisionmaking for resource management and critical area planning. This section suggests the use of such systems to solve many problems confronting state, regional and local governments.

Part C--THE NEEDS FOR INFORMATION: HOW TO DETERMINE THEM
Suggests ways in which states might go about determining their needs, uses, and sources for information that are based upon spatial data.

Part D--INFORMATION: A PRODUCT
Discusses the information products which can come from spatial information systems. The discussion deals with information from both manual and automated systems while emphasizing the relationship of information to decisionmaking.

Part E--DATA: RAW MATERIAL

Discusses the steps required for building a spatial data base. Covered are data collection and acquisition, data reformating, encoding, testing and use in a spatial information system.

Part F--INGREDIENTS OF A SPATIAL INFORMATION SYSTEM

Explores the processes required to develop information from data and the nature of the spatial information system. This section includes consideration of time and monetary requirements; personnel necessary for development and operation of the system; the major design decisions and elements; the equipment required; and the procedures and programs needed for operation.

PART A

Decisionmaking and Its Underpinnings: Data and Information

The farmer's new hired hand was amazing; he'd plowed a field in quick time, moved tons of hay, shod a horse in minutes, and gathered crops at amazing speed.

Then one morning it rained so the farmer gave him the job of sorting a bushel of potatoes into edible and seed types.

Minutes passed; an hour went by. When the hand didn't come up for lunch, the farmer went to check on him. The hand--with a small pile of potatoes at each side--sat dejectedly examining a potato.

"My gosh," exclaimed the farmer, "you were working so well! What happened?"

"Oh, work's no problem," replied the hand sorrowfully. "It's the decisions that kill ya."

* * * * *

In any decisionmaking process--whether simple or complex, a set of fundamental steps is involved--inventory, evaluation, decision. For example, in crossing a street, one inventories by looking and listening for oncoming vehicles; he evaluates their speed; and finally he makes a decision from a set of options resulting from the evaluation (do not proceed, proceed very quickly, or proceed at a relaxed pace).

* * * * *

Every organism takes in information. On the basis of that information, plus past information, experience and the makeup of the individual, the organism reacts. Such reactions sometimes take the form of a conscious *decision* followed by *behavior*: the expenditure of energy to modify the material world or to initiate a search for new information.

A person is an organism which may operate in this mode of responding to information--information which sometimes comes in very sophisticated forms--by deciding to attempt changes in her/his environment.

Some general statements about this phenomenon seem clear. The quality of the decision--whether or not it will in fact benefit the organism which made it--and the speed with which it is made depend a great deal on the familiarity of the form or "code" in which the information occurs and on the natural clearness of the code. For a person the number of ways information can be perceived is astoundingly large.

An aggregate of interacting people (a group or organization) can also be considered to have many of the characteristics of an organism--taking in information, evaluating, making decisions, and behaving. Many of the differences between the individual and the aggregate are simply ones of quantity rather than kind. We will discuss two of these differences. First, the rate at which information is assimilated, understood and used to produce decisions is slower the larger the aggregate. Second, as the number of individuals in an organization becomes very large (for example, a state government) the formats or codes of the information it considers are fewer in number. For large aggregates, most inputs are written documents and verbal statements; it does very little *direct* sensing or examination of the physical nature of the territory within its sphere of responsibility. For example, a government can't feel that the roads it has built are being destroyed by overweight trucks; it can't see its energy reserves being depleted; it can't taste cancer-producing substances in its water. It must get all of this information indirectly. Clearly, the more effective the mechanisms for conveying the information, the better the chance that good decisions will be made in time.

An organism which is cut off from all information about its environment will begin to fail to make decisions which are in its best interest as the environment changes. If the organism has only indirect information about its environment--examples for governments might be reports and statistics, i.e., information which has been analyzed, interpreted, and summarized--it may be able to make correct decisions but runs the risk that the environmental condition which is causing stress to begin with may advance to the point that the decision comes too late.

These two factors--(1) the slowness of large systems or organizations to gather, process and react to information, and (2) a method of operation which depends heavily on information coded in only a few forms--are part of the reason we have begun to face a crisis in our environment and in the use of our natural resources.

Decisions

In particular, the decisions we are concerned with deal with issues related to efficient use of our resources--land, water and energy--so that they are beneficial to us and we can abide the side effects of their use now and in the time to come.

Some individuals or groups, of course, lack the will to prevent spoiling our environment or depleting our resources because of their own short term gain. But as a society we also cannot get the correct information soon enough to allow us, with our method of operation, to take corrective measures. Our decisions will have long term and significant impact. When we speak of speeding the process of making decisions, we are not suggesting that there can be instantaneous response to complicated problems; rather, that decisions of high quality can be made in reasonable time, sometimes assuring that the situation that the decision concerns will not have deteriorated.

The concept of a "data base" is now introduced as a first step in suggesting that decisions can be improved through the systematic development and presentation of information to deal with resource planning and management.

Data Bases

The Concept:

In this discussion, a *data base* is defined as a collection of discrete symbols (numbers, letters, and special characters) located on some physical *medium*, arranged in a way so that there is at least one principal underlying organization or structure. A library card catalogue is a good example. Here, the underlying structure can be an alphabetical list of authors; the medium is 3 x 5 cards; and the data are the symbols on the cards describing books and their locations in the library.

Another example is a reel of magnetic computer tape which has recorded on it the most common type of soil found in specified acres of land in a county. The tape itself is the physical medium, the codes assigned to a soil type constitute the data, and the location of each acre--as understood from the position of each datum on the tape--could be the underlying structure.

Some Properties:

Some usually true observations about any existing general purpose data base are:

1) It results from some sort of project; some individual or team constructs it--frequently going to considerable effort.

2) It needs to be *updated* (modified and corrected as time progresses) if it is to continue to be of value.

3) It contains errors *regardless* of size, care of construction, simplicity of data, or quality of physical medium used.

4) It serves a function when allied with some process. The function may be as simple as supplying a telephone number (structure--alphabetical by name; medium--cheap bound paper; data--phone numbers, written quite small; process--looking up a name, finding the adjacent number). The function served by the data base might also be quite sophisticated--supporting far-reaching land use decisions, for example.

Referencing Schemes:

A great many data bases are currently used for problem solving at all levels of government. Access to these data bases is achieved through the use of referencing schemes. Some examples:

Referencing Scheme	Examples of Data Contained
Names of People	Salary, Social Security Number, Medical History, Criminal Record
Auto License Plate Number	Color, Owner, Serial Number
Street Address	House Value, Lot Size
Job Title	Person Employed, Duties, Salary
Transaction Number	Money Received, Paid, Transferred, Invested
Events	Schedules, Orders, Crimes, Accidents

Most states have extensive and perhaps sophisticated techniques or systems for storing and manipulating data that can be referenced by these and other schemes. One quite useful referencing basis has not been developed as extensively, however. It may be known by several names: geographic, land, locational, geodetic, or spatial position.

Spatial Data

When *location* or *position* is used as a primary referencing basis for data, the data involved are known as spatial data. For example, the elevations, in feet, of Clingman's Dome and Newfound Gap in the Great Smoky Mountains National Park are data. If the primary referencing basis for these data is the "Great Smoky Mountains National Park," or x miles south of Gatlinburg, Tennessee, on U.S. 441, or p degrees latitude and q degrees longitude, then the elevations could be referred to as spatial data.

Spatial data, then, are discrete symbols (numbers, letters, or special characters) used to describe some entity; these data are organized according to the location of that entity in the three dimensional world.

Normally, when it is desirable to describe things in the real world by spatial data, the objects are abstracted into some geometrical or mathematical form. For example, the top of a mountain might be represented by a point, a stream by a set of connected straight lines, and a lake boundary by a polygon.

Limiting the Scope

Spatial data (again, facts about the real world organized by locational coordinates) can be used to describe molecular structures, a human central nervous system, positions of books in a library or stars in the universe. Since the objective of this book relates to decisions about land and resource management, we now exclude several categories of spatial data. Specifically not considered are data which relate to:

1) *Conditions which change quickly in time*--in a matter of hours, days, or even weeks. Pollution levels, weather, tides will not be included, although average pollution at a point, climate, and ranges of tides could be included.

2) *Objects which move about in space*—such as automobiles, animals or people. However, data about flows of these objects past a certain point at a certain time might well be included.

3) Circumstances in which the locational identifier must be more precise than one meter to insure that the related data are useful or valid. The smallest distance separating two adjacent entities that can be distinguished from one another is called the resolution distance, or, simply, resolution. If the separation in distance is less than the resolution, the data cannot be used to resolve any difference in the condition or situation. (One meter is, in fact, an optimistic "highest" resolution, probably for the remainder of this century. The resolution of data bases developed for statewide application ranges from approximately 100 meters in New York to 800 meters in Colorado. (Shelton, 1968; and Colorado School of Mines, 1971)

Spatial Data Bases

We have discussed data bases in general (a medium containing numbers, symbols, or graphics organized according to some scheme). And we have commented upon the idea of spatial data (data describing entities in the three dimensional world where the *location* of the thing being described is an integral part of the description). A *spatial data base*, then, is a collection of spatial data, organized in such a way that the data can be retrieved according to their locational identifiers and, usually, in other ways as well.

Spatial Data for Environmental and Resource Decisionmaking

We have said spatial data relate to conditions, facts, and objects in three-dimensional space. Most spatial data bases which now exist use a two-dimensional referencing scheme such as latitude/longitude. The third coordinate (e.g., altitude) is either included as part of the data (rather than part of the locational identifier) or is implied by the nature of the data. For example, if the data describe soil characteristics, one understands that the top few feet of the earth's crust, regardless of altitude, are being described.

Data types which might be part of a state land and resource management spatial data base are exemplified by the following:

soils	- types, physical and chemical properties
vegetation	- species composition, age
wildlife habitat	- types, carrying capacity
hydrology	- ground and surface water, volume, flows
geology	- rock types, minerals and ores, physical and chemical properties
physiography	- elevation, slope, aspect
land use	- activity types, structure type
land cover	- types
transportation facilities	- types, capacity, schedules, condition, age
utility distribution systems	- service areas, capacity
historical features and landmarks	- importance, condition, ownership, use
census districts	- population, housing, other demographic information
fire districts	- equipment rating, insurance rating
zip code zones	- delineation of zones
center of employment	- types, work hours, number of employees, industrial classification
locations of police stations	- area of jurisdiction, facilities
pollution sources	- types, duration, occurrence
land parcel information	- owner name, address, value of land, value of structures, tax information

This presentation of a list of data types or variables whose data might be stored in a spatial data base does not imply that satisfactory storage schemes are easy to determine, nor that each variable will be stored in the same manner. Whether the geometric abstraction for a data type is best selected as a point, line, area or volume can be an important consideration in a particular storage scheme.

The development of spatial data bases to be used for analysis and decisionmaking is both an art and a science. Thus, when any data handling program is being developed, a key point to remember is that there is no single best way. (Hoos, 1971; Meltz, 1971; Kusler, 1975)

Inherent Difficulties

There are few spatial data bases around compared to the immense number of other types in existence in state government and in the private sector. Despite their powerful organizing structure--geographic location--and clear applicability to our areas of interest, they have not successfully materialized very often. We offer some suggestions as to why.

1) Size. An airplane pilot once said that the thing that kept Air Traffic Control from folding up completely many years ago in its attempt to keep airplanes from colliding was that "God packs a lot of airspace in three dimensions."

Anyone who has worked planning or management related to the land knows that He/She also puts a lot of surface area in two dimensions. Thus, any spatial data base used for land and resource considerations will either (a) not cover much area, (b) not include much detail, or (c) be very big. Very big data bases, regardless of their simplicity, are expensive to build and maintain.

2) Continuous nature of the referencing basis. In most data bases the referencing basis--the pointers about which the data base is organized--are discrete quantities. For example, an auto license number identifies a particular car; a name or social security number tags an individual person; a house number and street constitute a pointer to a residence. But spatial pointers do not enjoy any such autonomy: They are continuous unless some artificial scheme--such as dividing the landscape up into squares as on a city map--is used to make them discrete. Thus, there is no natural and completely satisfying one-for-one correspondence between spatial locators and the related data. There is an infinite amount of data potentially available about the real world; we can store only a small finite part. Thus, by choosing a particular technique for organizing the continuous into the discrete, we are screening out or "throwing away" an infinite amount of potential information. Clearly, it takes some sophistication and forethought to select a technique to represent the continuous real world and have a data base which will be useful in solving the problems of the future.

3) Continuous nature of the data. In addition to the continuum of two and three dimensional space just mentioned (i.e., the fact that our basic referencing scheme potentially has infinitely many points in it), there are also problems with the continuous nature of the data themselves. Soil type is probably a good example. Just as no two snowflakes are exactly alike, no two soils are exactly alike. Soils must be categorized into groups and a judgment made about which group a particular soil belongs to. In naturally continuous variables, such as elevation, the parallel issue of precision comes in: do we measure (vertically) to the nearest meter? To the nearest millimeter?

4) Abstraction of entities. The simplest reference that can be made in a spatial data base is to a point. But no material entity is ever just a point. Many of the things we deal with are either linear features, areas, or volumes so the referencing scheme becomes more complicated. Where is a house? Well, it's lots of places when you get right down to it. Do you define it by its corners in plan view? Do you select a single point, a "centroid," and define the house to exist at that point? Do you simply say it exists in acre "X", perhaps with many other houses? There are many fundamental variations in the ways the "real world" is and can be referenced. These varying methods can be incompatible, precluding any easy transfer of data or techniques for manipulating data.

5) Multitude of existing spatial coordinate systems. There are many spatial coordinate systems. Most of those in use for planning and resource management rely on the use of flat projections of curved surfaces. Many of the data which will be used to build a multi-variable spatial data base will come from data recorded with distorted and dissimilar methods of representation.

6) Existing but inappropriate data. While it is true that considerable data of the types important to this discussion have been collected, many of them are not directly usable in a spatial data base. This occurs principally because these data, collected by groups or agencies with specific missions to serve, have been assembled in non-uniform categories or have been interpreted in a specific manner for a particular purpose. For example, early soils data categories may not contain the necessary information that will enable measurement of some environmental effects of land use activities.

7) Effort required for development. The data in our base won't develop as a natural consequence of some already ongoing process. Others are more fortunate. As a clerk processes applications for auto license tags he/she may type the pertinent information about the car, owner and tag onto a multi-part carbon form. One of the copies becomes a part of a data base. Thus, the data base develops as a result of the tag-selling process which must occur anyway; all that is needed is an extra copy of the data. Spatial data bases about the environment have not evolved as consequences of other processes; the work starts almost from scratch in most cases.

8) The environment changes. One cannot get an entire spatial data base of any size developed before part of it is incorrect because some of the values in the real world will have changed over time. Land use is an example of a variable whose data values are changing somewhere on a daily basis. Even such stable phenomena as typography change drastically over time. For example, the Mississippi River was about 1300 miles long when LaSalle floated down in his canoes. When Mark Twain wrote about it 200 years later, it was less than 1000 miles in length. Not only that, very little of what was wet in LaSalle's day was still river in Twain's. And to further illustrate the futility of any attempt at a "permanent" spatial data base, Ole Man River has moved at least two towns from one state to another by its meanderings. The moral is that some data of all variables in a spatial data base are going to change over time. Some procedure for updating the base must be developed or the value of the base will be degraded by time.

> Further, different variables are of different value to the analysis and decisionmaking process and, of course, change at different rates. In some cases, the efficient thing to do is to note changes as they occur; in other cases replacement of all the data related to a particular variable is in order. Either way, there are difficulties and costs.

Spatial Data Bases - Maps

From the foregoing the reader may have inferred that people had to make their way in the world without benefit of *any* sort of spatial data base to aid them. This is not true at all if we relax the requirement that a data base be composed of discrete symbols (numbers, letters and special characters). A single map is a spatial data base and, for many purposes, a very good one.

Almost all of the information used to support land related planning and management has come from maps. Mapmaking is a well developed activity and, generally, data collecting for mapping improves every year. The piece of paper on which the map is drawn is a continuum which can represent the quasi-two-dimensional surface of the earth in a more obvious way than can a set of abstract symbols. ("A picture is worth a thousand words.") How many times has each of us been asked--"How do you get to...?" and responded, "Well, go to the second street on your left... Wait, let me draw you a map."

Why, then, should we spend millions of dollars on data bases composed of discrete symbols when maps are available? Well, if we should (and there is not universal agreement that we should), the answer is that maps alone are extremely hard to use in many of the analysis techniques that resource decisionmaking requires. There are precious few ways to combine graphic information with other graphic information. Decisions involving the space we live in are becoming more difficult all the time because of the larger number of factors with which we must deal. Techniques such as *overlaying* one map with another and looking through the composite clearly have limitations for some applications.

The reason spatial data bases composed of discrete symbols (numbers, letters, and special characters) offer promise is that, in the last 25 years we have learned a great deal about handling discrete symbols and we have developed both techniques and equipment (primarily digital computers) which can manipulate the symbols efficiently and quickly. Thus, an approach which seems basically less appropriate to the task may in fact serve us well--especially if some of the information produced by this approach can be maplike in character. A map is an analog of the landscape and, as such, has innate advantages in conveying information. (Catanese, 1968; Christensen, 1971; Clark, 1967; Haak, 1967; Hanold, 1972; Parker, 1971; Robinson, 1969)

Information Systems

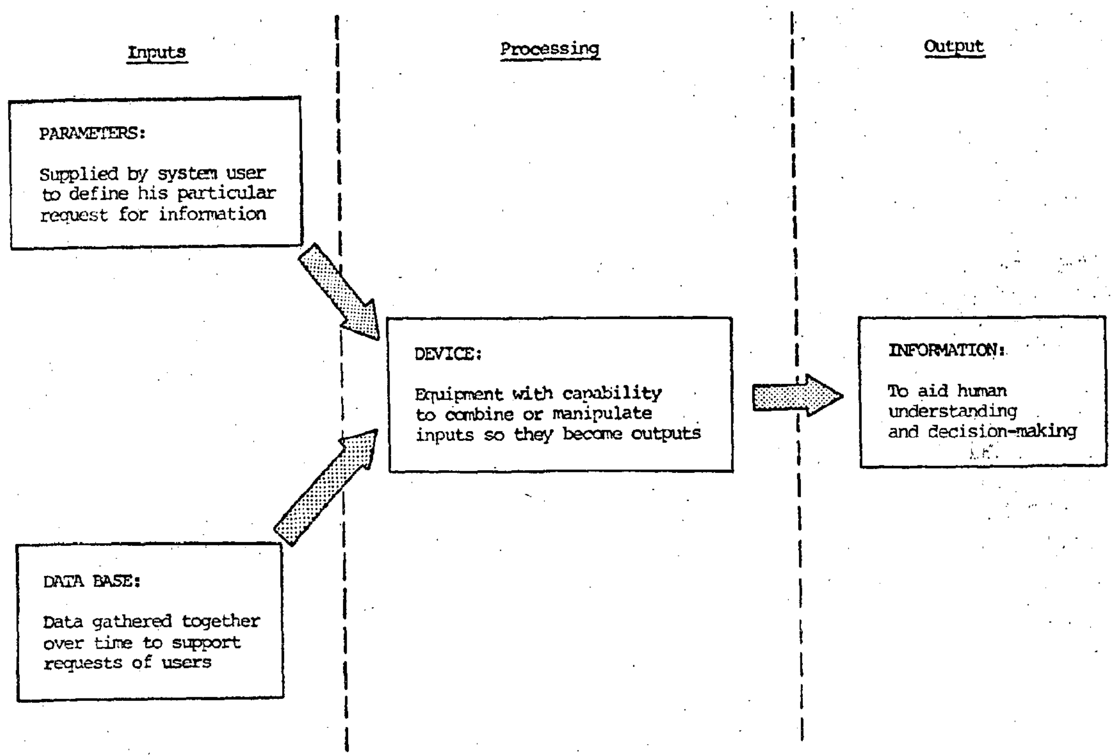
This issue of "processing" data in map (analog) vs. symbol (computer) form brings us to the matter of *processing* or handling data in general. The conceptual model we will use is that *data* are *processed* to produce *information.* Actually, the terms are not absolute because what is information to a person filling one role may be data to someone filling another. But the idea of a before-after concept, distinguishing the two states as *data* and *information*, turns out to be useful so we employ it.

An *information system* in the context of this material is a set of steps, or processes, which is executed by a "device" to produce information. We choose to call the symbols which are input to the process by two names: data and parameters. "Data" we have discussed along with its formulation into bases. *Parameters* we consider to be information which the user of an information system supplies at the time of use of the system. Such parameters might specify which data in the base are to be used, how they are to be combined, what the format of the resulting information--or *output*--is to be, and other specifications and/or constraints.

For an example, a professor may assign a student the task of compiling a typewritten bibliography of the works of Shakespeare. The data base might be a library card catalogue; the parameters are such descriptive terms as "bibliography," "Shakespeare," "typewritten,"; the device is the student with his eyes, pencil, typewriter, etc. who produces the information.

Following we present a diagram of an information system in a general nature:

A Garden-Variety Information System



Spatial Information Systems

Based on the preceding discussion of spatial data, data bases, and information systems, it is now possible to construct an important definition: A *spatial information system* is an information system which has as its primary source of input a base composed of data referenced by spatial (or land, or geographic) coordinates. The system accepts parameters, examines its data base, and provides information for decisionmaking and resource management. In an *automated* spatial information system a major part of the device which does the processing is an electronic digital computer. Much of the data base it uses is stored on electronic or magnetic tapes or disks. A *manual* spatial-data information system does not involve use of a computer.

An Example

For illustrative purposes we present a trivial example of a manual, discrete symbol, spatial information system.

Suppose the farmer, who opened this part, owns a 100-acre farm and wants a systematic method to determine how to use each acre. He elects to use a *Keysort** system. First, he inventories *each* of the 100 acres and assigns value to each of several variables.

Variable	Values
Pasture	Yes or No
Steep	Yes or No
Rocky	Yes or No
Acid Soil	Yes or No
Flood Prone	Yes or No

He could now put these data into a spatial data base by writing the location of each acre on a separate Keysort card and "clipping" the appropriate holes corresponding to each variable if the value for the variable is "yes."

**Keysort*—a registered trademark of McBee Systems, a division of Kimball Systems, and known as Unisort and E/Z sort.

Keysort is a manual, digital information system. It consists of a set of identical cards, each of which has holes around its periphery. Each card might represent an element in some group (e.g., a car in a fleet). Each hole position in the deck represents a variable which relates to the elements (car is owned or leased). Any hole in any card may be clipped out of the card's periphery so that it forms a groove, thus allowing the associated variable to take on one of two values. Once the deck is prepared in this way, a slender rod or "needle" may be inserted into a hole position of the deck and the clipped cards, which the rod cannot retain, "shaken out" (owned cars could be separated from rented ones).

Now he can process his spatial data base. If he puts a "needle" through the "rocky" variable he can "shake out" all the rocky parcels. In like manner he could separate the flood prone parcels from either the rocky or the non-rocky parcels. He now has a capacity to obtain new information about his farm--from his Spatial Information System. Whether he can determine how to better use his farm depends on whether he selected the correct variables for his inventory, allowed a sufficient number of data values for each variable, collected the data accurately and encoded it properly by punching out the correct holes, and processed the deck in a meaningful way.

Notice that while he processes the data--even though the location is written on each Keysort card--he is not getting a graphic picture of the results. So to get a feel for the spatial aspect of the results he will probably have to plot them on a map of his farm. (Bricker, 1971; Holden, 1968; Hoos, 1971; Horwood, 1967)

PART B

Potential Uses for a Spatial Information System

> A rancher whose property was adjacent to a railroad track, addressed his dog who had just returned, spent and panting, from chasing a locomotive: "Yuh durn fool, what would yuh have done with it if yuh'd caught it?"

Part A has briefly discussed conceptually how data bases and information systems may be fueled by spatially distributed data. This part of the book describes some of the areas which could realistically benefit from having an appropriate spatial information system available.

To preserve the focus of discussion, we note again that the reason to develop and use a spatial-data information system is to provide better information for decisionmaking. Included under decisionmaking are: policy formulation, planning, and management of a program. These components are not completely separable and could be referred to by many other terms.

Arguments for a Centralized Spatial Information System

We slant our discussion towards the view of states. We see the state acting in three primary roles in its use of information derived from spatial data: as a supporter of sub-state region and local decisionmaking efforts relative to land use and other activities; as a responder to federal incentives and directives in a variety of areas; and as an increasingly active participant in land and water management, environmental protection, and energy and natural resource concerns. Without doubt, the problems a state faces in acting out these roles are intertwined and complicated to an amazing extent.

Not only is it difficult to gear up separately for each of the several activities within each role, it may also be inefficient, because the information bases for many of them have a great degree of overlap. For starters, they all deal with the same space; and one has only to look at the myriad of different map formats, styles, and scales to know that many of the common elements can be disguised if the purposes for which they are produced are independently targeted.

Another point in favor of a cohesive development of an integrated data base is the "other side of the coin" of overlapping responsibility: those areas where no one has responsibility. For example, at the federal level, the Department of Agriculture has responsibility for information about the volume of earth from the surface to five feet under; the Geological Survey is concerned with the volume from the bedrock down. What about the volume in between, when it occurs? Is a more integrated approach warranted?

Two types of systems relating to land and geographical concerns have grown up over the past several years. One, the Geographical Base File (GBF), is exemplified by the Bureau of the Census' Dual Independent Map Encoding (DIME) system. The second, "land information systems," like the Canadian Geographic Information System (CGIS), is designed to cover larger areas of open land. These two types of information systems operate on very different bases, and are not compatible with each other--a significant problem that is just beginning to be solved. DIME, for example, is very much concerned with already developed areas: Street designations are central to its spatial locators. Conversely, CGIS deals with spatial locators based on natural rather than man-made elements. (Arms, 1968; Tomlinson, 1967, and Land's Directorate, Environment Canada, 1973)

Incompatibility between these types of systems becomes evident where developed area meets an undeveloped one: the urban-rural interface. This is also the area where most system updating occurs. As buildings are erected, the street pattern is modified and supplemented. In addition, more is learned about the natural environment and land use activity changes. These are also the areas where it is most necessary to know the impacts of development. And these are the areas where the designs of existing spatial information systems simply do not allow them to mesh.

All levels of government must begin to deal with conflicting demands of citizens. For example, the desire for an unaltered natural environment vs. the need for extraction and processing of resources that provide our fuels and energy. Presumably, good information, well used, can help us achieve balance among complicated, conflicting demands.

Land and Its Use

Discounting the possibility of sudden catastrophe, the strongest factor in how things will be tomorrow is how they are today. A planner or manager who fails to provide himself/herself with information about the current state and characteristics of the environment will probably misplan and mismanage.

Perhaps the most important variables in a spatial data base are:

1) What now exists on the land (land cover and resources)

2) How the land is employed (land use and human oriented activities)

3) What is legally permitted to happen to the land (zoning and legal control)

Once the present state of the environment, or the portions of it with which we are concerned, is recorded in a form amenable to processing, we can begin to make decisions about its conversions to some other use. A spatial information system could be useful in dealing with at least three general categories of issues:

1) Determining the effect a particular activity or land use will have at a particular location (sometimes called environmental impact analysis).

2) Given a particular activity, with its characteristics known, determining a set of locations where it might be placed (sometimes called locational analysis).

3) Given a particular location or site, determining a set of land use activities which might well be placed there (sometimes called site analysis).

We now briefly look at a variety of specific areas in which Spatial Information Systems could have an impact. The thrust of presentation is mostly by example and is far from comprehensive. We hope the reader will add to and improve our lists. The format we will use, for the most part, is

(1) Examples of types of spatial (and other) data which might be stored;

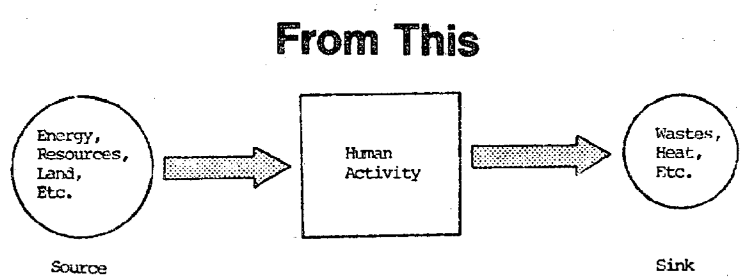
(2) Advantages which might accrue by careful use of the data in (1);

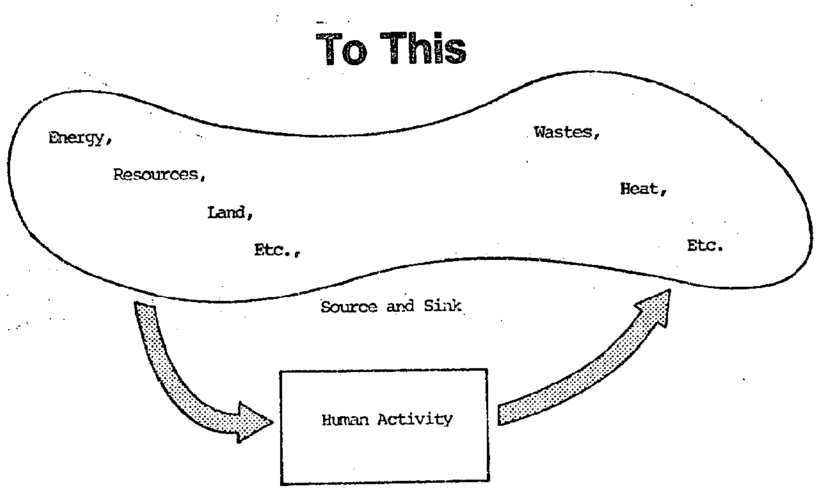
(3) Some federal programs which might be served.

An important thing to notice in the following is the degree of overlap among variables of different areas of concern.

The Natural Environment

Knowledge of the natural environmental state of the land is central to a determination of what should be preserved, what should be enhanced, what activities could be supported, what impacts are likely to occur from given uses, and a host of other questions. The effect of our activities on the natural environment has changed our mental model of the world--





This change--the realization of "spaceship earth"--has occurred in the last decade or two and has had many profound and far-reaching effects. As a partial result, many of the first attempts to use spatial information systems to support decisionmaking have had the storage of natural science information as their basis.

(One of the referees of this work was asked if the diagram above made sense to him. He replied, inelegantly but accurately, "Of course, you mean we're living in our own toilet.")

Storage of spatial (and other) data about:

Climate
Bedrock
Surficial geology
Physiography
Hydrology
Soils
Vegetative cover
Wildlife habitats

Could help us:

Identify, delineate and manage areas of critical environmental concern
Analyze land carrying capacity
Write environmental impact statements

Programs in this area which could benefit from a spatial information system include the broad range of state natural resource and land management agencies. All these programs rely on analysis of natural resource data in a spatial context.

Some related federal programs:

HUD "701 Comprehensive Planning Assistance Program"
Appalachian Regional Development Act
Coastal Zone Management Act
Flood Insurance Program
Rural Development Act

Energy

Energy potentials begin their service for humankind in many forms--oil, gas, coal, hydraulic head, wind, tide, sun, fission, fusion--and always wind up in the same way: heat.

The problems associated with the efficient and useful transfer from energy potential to heat are myriad; much of the time we throw away large amounts of energy because it does not serve a particular process, e.g., nuclear power plants discharge vast quantities of heat into rivers to the detriment of the fish and the impoverishment of humans paying for waning gas supplies to heat their homes. A spatial information system is not the answer to the sensible use of energy but it is a tool which can help reduce energy waste. Spatially distributed data on energy sources, energy movements, and energy use of all kinds could lead to a greater understanding of our wastefulness and how to prevent it; and to energy sources and how to tap them.

Storage of spatial (and other) data about:

- Potential energy sources
  - Location
  - Size
  - Cost of extraction or tapping
  - Surrounding environment
  - Access
  - Processing capability
- Energy distribution systems
  - Location
  - Paths
  - Capacities
  - Intermediate storage facilities
  - Types of energy conveyed
  - Degree of hazard
- Energy use patterns
  - Industrial
  - Residential
  - Peak usage
  - Distribution among users by user characteristics

Could lead to information

- Allowing analysis of:
  - Costs of moving energy
  - Remaining available energy reserves
  - Efficiency of different allocation schemes
  - Waste
  - Heat pollution
- Delineating:
  - Areas of danger to humans
  - Environmental impact
- For developing:
  - New distribution lines
  - Resource allocation schemes

Some related federal programs:

- Pending Federal Energy Legislation

Human Resources

It is for people that we operate our governments. It is primarily people who use the land, the energy, the resources, and it is, in part, people who feel the effects of its ill use.

The vast amount of data about people is not stored in spatial form for several reasons:

1) They move around--day to day and year to year

2) We protect their privacy to a certain extent

3) The techniques for storing spatial data have not been well developed.

But the storage of information about human resources and conditions in a spatial context offers two major advantages:

1) It allows us to deal in a very direct manner with our primary concern: humankind, and

2) Many sets of data have been developed, largely by the Bureau of the Census in such a way as to permit relatively easy loading into a spatial data base, even though--for reasons of privacy and reasons related to the mission of the census--the "grain" of such two dimensional information storage is very coarse for most applications.

Storage of spatial (and other) data about humans:

Where they live
How much they consume
How much they earn
How old they are
What they discard
Where they play
What crimes they suffer
What mishaps befall them
What facilities are available for their employment, shopping, learning

Could lead to information

To plan for:
- Mass transit
- Recreation areas
- Police unit allocation
- Pupil assignment

To analyze:
- Migration patterns
- Population growth
- Crime patterns
- Welfare needs

To manage:
    Public and government services

Some related federal programs

Human Resources
Title I, Elementary and Secondary Education Act
National Health Planning and Resource Development Act, 1974
Public Assistance Programs
Housing and Community Development Act, 1974
Housing Assistance Plans
Revenue Sharing
Community Development Block Grants

Areas of Critical Environmental Concern

Areas of critical environmental concern are those geographic areas which are important to the needs of man. Not only do they perform functions related to the health, safety, and welfare of the general public, but they may also serve economic and educational needs as well. Areas become of critical environmental concern when natural resources become scarce or are threatened through the actions of man, or when the areas themselves present a threat to the human population.

Storage of spatial (and other) data about:

Agricultural lands
Natural and scenic resources
Soils
Aquifers
Geology and geologic hazards
Wildlife habitats
Vegetation
Floodplains
Wetlands
Scientific areas
Wild and scenic rivers
Cultural activities
Transportation networks

Could lead to information

To facilitate:
    Identification of unique resources
    Management of designated areas
    Determining relative importance of kinds of resources

Some related federal programs

Wild and Scenic Rivers Act
Coastal Zone Management Act
Clean Air Act

Water

Water is the most important resource to the functions of natural environmental processes and human activities. It is a dynamic resource--its movement, both as surface water and ground water, creates a very broad management problem. Through information in the spatial context we can better analyze and manage our water resources.

Storage of spatial (and other) data about:

Natural bodies of water
Supplies
Use patterns
Recreation needs
Climate
Water sheds
Elevations
Industrial locations
Settlement locations

Could lead to information about

Floodplains
Availability of clean water
Irrigation
Pollution (potential and existing)

Some related federal programs

Water Pollution Control Act - Sections 201, 208, 303(e)
Federal Flood Insurance Program
Wild and Scenic Rivers Act

Natural Resources

Natural resources are both finite and necessary for the survival of man and the maintenance of a quality of life. Some natural resources are renewable with proper management while others will simply run out. A continuing supply of information will be needed for a proper evaluation of how we should use our resources wisely.

Storage of spatial (and other) data about:

Forests
Mineral sources
Energy sources
Rivers, streams, lakes
Wildlife and fish
Agriculture
Harbors
Geology

Could lead to information

To facilitate:

- Timber management
- Preservation of agricultural land
- Conservation of energy resources
- Wildlife management
- Market analysis
- Resource allocation
- Resource extraction
- Resource policy
- Recycling
- Resource utilization

Some related federal programs

- Rural Development Act
- Appalachian Regional Development
- Coastal Zone Management Act
- Strip Mining Legislation
- Price Controls on Interstate Commerce
- DOI Bureau of Land Management Programs
- DOI Fish and Wildlife Programs

Agriculture

The production of food has received increasing attention with a growing world population and shrinking agricultural productive lands. Demands for grain and other crops has increased tremendously as the United States has drawn closer to the world marketplace. The need for good agricultural management becomes more obvious as we try to meet the needs of others. Data demands will also increase as we seek solutions to this growing problem.

Storage of spatial (and other) data about:

- Land Conversion
- Soils
- Geology
- Crop productivity
- Climate
- Hydrology, water supply
- Irrigation
- Erosion
- Crop disease, blight
- Insect control
- Pesticides
- Fertilizers

Could lead to information

To facilitate:

Crop management
Protection of agricultural lands
Conservation practices
Prime agricultural land policy and management

Some related federal programs

Rural Development Act
Several USDA Programs
Farmers Home Administration Programs
EPA Water Pollution Control Act

Crime Prevention; Law Enforcement; Criminal Justice

The Criminal Justice System has many potential applications for spatial data; to assist the system in predicting likely points of criminal activity; to enable efficient allocation of resources through systematic identification of locations warranting increased manpower, analysis, or resource allocation. Although spatial data are routinely collected by law enforcement agencies, frequently it is done in a non-uniform manner that lacks sufficient precision to be tactically useful or to enable ready comparisons of location information from occurrence to occurrence.

The 1973 report of the National Advisory Commission on Criminal Justice Standards and Goals called for development in "medium and large cities" of a "...computerized geographical coding system..." The Commission noted that such data could be useful for patrol allocation and investigative purposes. Another example of spatial data use in law enforcement is in establishing precise location of traffic crashes. The Federal Highway Administration's Highway Safety Program Standard 4.4.9 calls for "a procedure for accurate identification of accident locations on all roads and streets" in connection with a "systematically organized program" to "maintain continuing surveillance of the roadway network for potentially high accident locations."

If spatial data systems or methods were instituted in every jurisdiction that enabled identification, with sufficient particularity, of locations of criminal occurrences, particular premises with a history of repeated criminal attack could be singled out for target hardening attention as well as for tactical patrol attention.

Storage of spatial (and other) data about crime:

Where (specifically) crimes occur
Where stolen property is recovered
Where arrests are made
Where high risk businesses are located
Where arrestees live, were schooled

Could lead to information

To plan for:
- Selection of sites or premises for target hardening attention
- Procedures for establishing risk ratings for particular locations
- Tactical (as opposed to strategic) patrol allocation
- Selection of particular locations for detailed crime prevention analysis
- Crime pattern recognition
- Selection of areas or schools for delinquency prevention attention

Some related federal programs

- Law Enforcement Assistance Administration Programs
- Crime Control Act, 1973
- Omnibus Crime Control and Safe Streets Act

Civil Defense

Civil Defense has been established to respond to the need for natural or human-caused disaster or one caused by war. As such, civil defense plans for both short-term and long-term aid to communities across the nation.

Storage of spatial (and other) data about:

- Population distribution
- Sources of food
- Geologic activity (earthquakes)
- Transportation
- Military installations
- Public facilities
- Medical facilities
- Rescue equipment

Could lead to information

To facilitate:
- Alternative disaster relief plans
- Need for stockpiling of foods and medical supplies
- Evacuation plans
- Proper designation of disaster relief areas

Communications

Communications represent the way in which man stays in touch with occurrences around him and through which he transmits information. The physical requirements of communication systems have considerable impact on the natural environment. In order to maintain harmony between the two, information on spatial data must be kept before the decisionmakers.

Storage of spatial (and other) data related to:

Communication stations
Population
Geography
Power sources
Current events
Technical information

Could lead to information

To facilitate:
Siting of transmission lines
Location of equipment
Education

Transportation

The movement of people and materials for economic, social, and recreational reasons requires consideration of spatial data. Analysis is required on levels ranging from small scale local transport to the national and global scale.

Storage of spatial (and other) data about:

Highways, roads, interchanges, etc.
Rapid transit
Airports
Seaports
Railroads
Origins and destinations of travelers
Population shifts
Centers of employment
Commercial traffic

Could lead to information

To facilitate:
Alternative transportation plans
Locational analysis
Mass transit
Energy conservation

Some related federal programs and agencies

Federal Railroad Administration
National Highway Traffic Safety Administration
Office of Pipeline Safety Administration
Highway Beautification Act
Federal Aviation Administration
Urban Mass Transit Act
Emergency Medical Services Act
Highway Safety Act

A Common Format for Data

As the reader will have observed, some of the items mentioned under the heading "Storage of Spatial (and Other) Data About" were repeated; many more could have been but were not simply for space reasons. This suggests the obvious: many of the problems our governments face in serving the people of our socity are interrelated and have need of the same basic data. A well-thought-out, well-constructed spatial data base, made flexible so that different kinds of data might be inserted and analyzed as the needs arise, could provide a powerful tool for making good and timely decisions in a wide variety of areas.

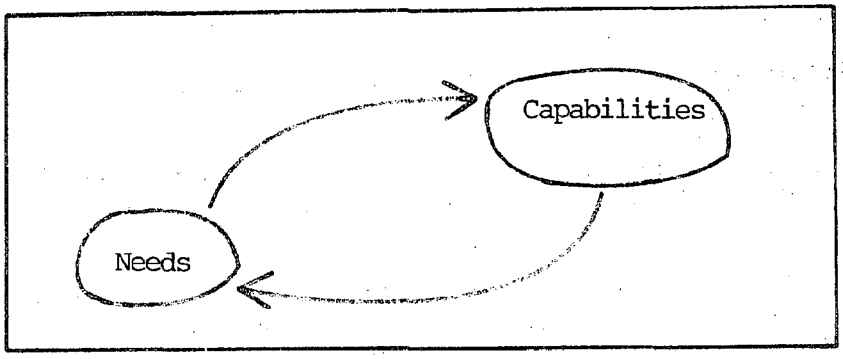
Probably of greatest importance to state government in this area is to avoid the development of a number of incompatible spatial data bases for special purposes. An advantage of symbol oriented (digital) spatial data bases (amid, of course, some disadvantages), over necessarily separate graphic data bases, is the automatic processing capability which allows their manipulation and handling. It is easy, however, to throw this advantage overboard by constructing separate digital data bases in such a way as to deny their use on a variety of problems.

(Environmental Systems Research Institute, 1974; Department of Regional Economic Expansion, 1970; Fry, 1967; Kusler, etal., 1975; and Meyers, Durfee, and Tucker, 1974)

PART C

The Needs for Information: How to Determine Them

Question:	What do you want?
Retort:	What do you have?



It is popular to say that one must first determine what the requirements for data and information are before an attempt is made to provide a capability to make good decisions. This implies a two-step process: determine needs, build capability.

It is not so simple. Often people cannot articulate their needs because they have little idea what is possible. And once they know what is possible, and begin to use it, a new need is generated.

The lesson:

There is no neat, straightforward procedure for determining data needs. The process continually cycles between a recognition of what is needed and what is possible.

<u>Inventorying Data Sources and Uses</u>

Before trying to identify what data are required for better decision-making it is vital to find out what data exist and the uses they are put to. Given an organization the size of a state government, this is quite a task, even if it pales in comparison with the task of determining needs and requirements. To determine existing sources and uses of existing spatial data one should first define spatial data in a broad form for those potential respondents to spatial data survey. One state evolved the following definition prior to a survey of spatial data sources and uses.

DEFINITION OF SPATIAL DATA

For purposes of the study by the Spatial Data Task Force the following definition, amplified by the discussion below, is used.

> Spatial data are any symbols, graphics, or information--residing on some physical medium or device--which are associated with a geographic or position locator.

Spatial data, then, are any data which are referenced by their location in space. Some important classes of spatial data are:

- Maps. A map usually depicts conditions, either of the environment or of a human population, with reference to points, lines, or areas of the earth's surface.
- Some photographic materials which can be related to specific geographic areas.
- Files of information which contain spatial locators. Such files might be handwritten, printed, computer written or computer readable.

In identifying any set of spatial data three elements are essential: (1) the *data*, (2) the physical *medium* on which they are recorded, and (3) the spatial *locator*. Some examples of each of these follow:

Data (examples)	Spatial Locators (examples)
slope of the earth's surface	names (of towns, counties, schools, any entity of known physical location)
incidence of crimes	geographic coordinates (latitude-longitude, state plane coordinates, Carter coordinates, etc.)
location of state office facilities	street addresses
historic markers	mile stations (highway, river)
average household income	districts (census, school, voting, fire, etc.)
points of employment	
flood plains	
average pollution levels	
natural gas usage	
land use and land cover	
disappearances of persons	
electrical transmission line corridors	
traffic flow averages	**Physical Media (examples)**
employee work stations	paper (maps, charts, tables, card files)
property values	photographic film (aerial photography)
student enrollments	computer readable tapes, cards or disks
core drillings	cathode ray display tubes
wells	scale models
broadcasting stations	
soil types	
slide-prone areas	

Once those upon whom the survey depends understand what is meant by spatial data, questions like the following are likely to get reasonable answers provided, of course, there is sufficient backing from governmental administration to insure that time is devoted to the survey work.

1) Does your agency buy or otherwise obtain, published spatial data or information? If yes, identify each document, series, or file: title, common usage title, pertinent dates, description, frequency of acquisition, cost of acquisition, aerial coverage, scale, resolution, locator or coordinate system, medium of storage, format, etc.

2) Does your agency collect spatial data of any sort? If yes, identify and describe as in 1) above. To what extent are such data available to others?

3) Does your agency publish, distribute, or transmit spatial data?

4) Does your agency publish research reports based on spatial data?

5) Does your agency process (update, revise, summarize, record, compare or extract information from) spatial data? Describe.

6) Does your agency possess or use any special equipment (digitizers, plotters, photo-based equipment) for processing spatial data?

7) Does your agency use computer programs to process spatial data? Indicate purpose of program, machine used, and other appropriate information.

8) Does your agency get requests for spatial data (or information derived from such data) from other state agencies, federal agencies, the public, the private sector, the press? Please attach a list generally classifying the requests and how they are serviced.

9) Does your agency supply spatial data or information to other agencies, persons, or entities because of statute, administrative order, remuneration, or for other reasons? Please describe (or reference answers to previous questions).

An expansion of the skeletal questionnaire above, if good response can be obtained, will probably serve as the basis for (a) a good picture of the sources and uses of spatial data among the respondents, and (b) a contact network of those in the government who are concerned with the work with spatial information. The importance of this contact network cannot be overemphasized in the next step: determining needs for new spatial information to improve decisionmaking or to make existing efforts more cost effective.

Assessing Needs

As indicated by previous sections of this book, a data base composed of spatial data could be useful in many applications. While the development of a generalized data base having common formats and uniform data retrieval techniques may be a worthy goal, this type of comprehensive system cannot be developed all at once. Certain issues may be given high priority over others which do not require immediate action.

How, then, does a state decide which issues and programs should benefit first from development of a spatial information system?

An intensive evaluation effort may provide an answer for this question. Some method of determining a list of state, regional, and local government information requirements that might benefit from use of a spatial information system should be derived. A priority should then be attached to each need. By matching available financial, time, and personnel resources against this prioritized list, a reasonable idea regarding the proper elements to include in the initial data base effort can be formed. (Lundberg, E.J., 1967)

We propose an omnibus approach to determining the list of needs. The following activities are likely to produce many expressions of needs; a great deal of overlap will also occur.

(1) Make use of the contact network of persons which came out of the survey of sources and uses of spatial information. Get those people together, formally and informally. Have some brainstorming sessions with them. All segments and many levels of government should be involved, both for the information they can provide and to insure their future cooperation on any centralized spatial information system development effort. From this group select a few people to augment the task force which did the "sources and uses" survey.

(2) Examine existing and proposed legislation (Federal, state, local) for legal requirements for information. For existing legislation, presumably, these requirements are already being met. "How well" and "at what cost" are questions which come to mind. The process of determining legislative requirements is sometimes called *demand analysis*.

(3) Examine the missions of the agencies within the government. Look at their legislative mandates and operational realities. What needs for information are implied in the performance of the required missions? How many might be supported by a base of spatially distributed data?

(4) In like manner with (3) look at all offices or departments within the agencies. Continue to assess the information needs of various entities until the level of individual job description is reached and analyzed. One very useful spinoff of this kind of research

effort is uncovering the differences between what people, offices, et cetera are doing and what they are "supposed" to be doing. Then either the mission descriptions or behavior can be modified, as appropriate. Looking at these governmental entities in terms of the data they need and the information they produce is a most basic approach since most of them are basically information processing systems anyway. It isn't even farfetched to look at "the state office building" as a giant computer: It's plugged into electricity; data comes in (by document and telephone) and information goes out; it has internal information circuits and mini-information processors (people) who conduct the operations.

(5) Examine information needs articulated by suggestions or complaints from the public. If an agency isn't performing to the satisfaction of the public, that agency may be operating with insufficient data, or trying to use information that is insufficient in form or quality. In this type of situation, might there be any implications for use of a spatial data base?

(6) Examine errors and mistakes of the past. Were Federal funds lost because of a lack of timely information? Was a lawsuit filed against the state because of misallocation of funds due to faulty information? Was there racial imbalance in schools because of lack of information about who lived where? Was a major land conversion permitted because its ramifications could not be foreseen? A major reason for mistakes is lack of the right information at the right time.

(7) Look at areas of state fund expenditures. Where is money being spent for information? When money is spent for products, materials, etc., could better information reduce the cost or increase the quality of these products? A comprehensive look at the state budget in this light could be quite beneficial.

(8) Are any special projects under way which will generate data or which could benefit from spatial information? Is the state sponsoring a reassessment of all real property? Is a "housing needs analysis" being conducted to qualify for Federal funds?

(9) Pick out a sample of key individuals in state, regional and local governments. Conduct detailed interviews with them to determine how they carry out their duties, paying particular attention to data used and information produced. Then randomly select—perhaps from the state telephone directory or payroll list—an equal number of people and repeat the process.

(10) What requests for information are received from individuals or the private sector? Particularly look at private sector organizations which provide information to the state. Are data available (or potentially available through a spatial information system) to them which would cut costs?

These evaluation steps likely will identify much more than just spatial information needs. Thus the investigation could be a collaborative effort sponsored by several agencies. The spatial component, however, must not become lost in a morass of other types of data and information, which may outnumber it several times over. Most organizations, with governments no exception, go through self-evaluation. If, during such a process, spatial data and information requirements could be considered, the evaluative process could be quite helpful in the design, development, and maintenance of a system.

For governments going through a self-evaluation process, there are two admonitions: (1) Pay attention to regional and local governments--in fact, concentrate on them, since sub-state governments still make most of the major land use decisions. (2) Don't deliver an edict to all state agencies to cease and desist from developing new systems to gain information. Any analysis of information needs should be dynamic, ongoing, and able to cope with--or perhaps influence--the direction of current program development. Also, agencies developing new information systems are probably doing so in response to strongly felt needs. Few things will alienate these responsible parties more than forcing a halt to their data gathering or program development activities while a lengthy inventory of information needs is conducted. (Haak and Bigger, 1966; Lockheed Missiles and Space Co., 1965; Shawn, 1968.

PART D

Information: A Product

"And the Judge (with the seeing eye dog) wasn't going to look at the twenty-seven 8x10 color glossy photographs with the circles and arrows and a paragraph on the back of each one."

--From Alice's Restaurant
by Arlo Guthrie

Introduction

Part A discussed the concepts of a spatial information system and described how such systems support decisionmaking. Part B suggested some of the areas in which a spatial information system might be useful and encouraged governments or other agencies with interests in those areas to define their interests and needs specifically. Part C offered some specific thoughts on determining data sources and information needs.

The remaining parts of the guidebook will describe, in some detail, the various elements of a spatial information system and the connection between those elements. Although logical progression--or "development process" through time for a spatial system is:

DATA ⟶ MANIPULATION (Analysis) ⟶ INFORMATION

this discussion will focus initially on information (the product) for two reasons: First, the products--the information--from a spatial information system are most important. The accuracy, timeliness and relevance of the information product are, of course, functions of the data and the way they were handled. But the product and its use are the *raison d'etre* for the information system. In the final analysis, *the utility of a spatial information system is the primary measure of its worth.* This fact is amazingly easy to forget by those involved with constructing portions of the system.

The second reason for discussing information products before data input is that we are aware that administrators are a prime audience of this book and we are mindful of C. P. Snow's observation about limits on their time:

"To be any good a scientist has to think of one thing deeply and obsessively for a long time. An administrator has to think of a great many things, widely, in their interconnections, for a short time."

(Snow, C. P., 1955)

This section of the book is intended for a fairly wide audience: decisionmakers (those actually responsible for initiating courses of action related to land conversion, resource allocation, etc.), the advisors of decisionmakers (professional planners or consultants) and designers of systems to supply information to the two previous groups. An apology is offered here in advance for the fact that there will be some shifting in the discussion as various audiences are addressed; but we absolve ourselves by opining that each needs to know what the other is involved with.

Overall Requirements for Utility

To have a chance to be useful in decisionmaking, a product of a spatial information system must meet several criteria:

1) The decisionmaker must know it is available.

2) He must be able to understand it.

3) He must have some reason to believe that it is worth his time to determine how to use it.

4) Assistance to aid the decisionmakers' understanding of the product must be available.

5) The product must be available at the time it is needed.

6) It must be relevant to the area of concern.

7) It must have considerable accuracy and integrity; if the product lets the decisionmaker down, a long time will elapse before he again depends on such information.

Classification of Spatial Information System Products

Products from a spatial information system can be classified in several ways. We use the terms *origin, media, format, purpose,* and *audience.*

Origin: A product can come from a manual process or an automated device. Combinations of the two are possible, as when color markers are used to enhance computer output. It is perhaps useful at this point to state a definition of an Automated Spatial Information System. An Automated Spatial Information System is one in which a significant part, but never all, of the systems functions are carried out by electronic digital computing machines.

Media: We use the term "media" to denote the *carriers* for the information presented to the decisionmaker. Common media are paper, photographic materials (opaque ones like photographs; and translucent ones like slides and films), and electronic visual devices like cathode ray tubes. Three dimensional electronic displays activated by laser beams--called holograms--may be available in the future, but more conventional products are now available which can meet more important, if less exotic, criteria. Almost all products of existing spatial information systems are designed to respond to the sense of vision in some manner.

Format: While the number of visual media which carry information are limited, the number of forms or formats that information can assume are without limit. An infinite variety can be obtained with *characters*--the 26 letters of the alphabet, 10 arabic number symbols and some special symbols. This type of information is called *character based.*

Character based information can appear in the form of text, tables, lists, formulae, etc. The way in which information is organized has a tremendous impact on whether or not it will be useful. Character information can be processed by an individual in *serial* fashion (like a reader "processing" this line of text) or in *search* mode--a procedure in which a person examines unconnected groups of characters in order to find desired information. Looking up a number in a telephone directory exemplifies use of the search mode--followed, of course, by serial mode.

For purposes of mental model building, the best products allow a user of character based information to quickly grasp two things: the overall *scheme* of organization of the information (revealed by tables of contents, sections on "how to use this information," etc.) and the subject of the information itself (illustrated by introductions, table titles, lists of parameters relating to the information, etc.). Development of products which can meet these criteria is an art and a science.

Graphic information--pictures, photographs, drawings, maps, displays, graphs, diagrams, etc.--is equally as versatile as character-based information. In manual systems, graphic products are produced by

- photographic techniques
- drafting
- drawing
- cartographic techniques

With automated systems, graphic products are usually made

- by pen on paper with a device called "plotter;"

- with electrical charges or magnetic flux on a specifically treated glass surface. (The most common form of device is the cathode ray tube [CRT]. Mention of the TV tube--although an obvious example of a CRT--is misleading because most graphic products displayed do not resemble the "photographic" image seen on television);

- with "hardcopy" machines which can reproduce, on paper, the images appearing on CRT-like surfaces;

- with characters (letters, numbers, and symbols) printed on paper--not for their traditional meaning, but for their visual density. (An explanation of this interesting technique will follow later).

In any of these instances, the information product usually is a diagram or drawing without real limits on its diversity. This type of display may be composed of points, lines, and shadings of areas. If a graphic product is on an electronic display, it may be possible to quickly change some of its elements to allow an examination of alternatives or to create an animation effect.

Simplistically, character-based information is read while graphic information is viewed. Both can help a decisionmaker form a more complete mental model of an issue, but provide information in different ways.

It is seldom that any information is either totally character based or graphic. Combinations of the two are the most effective (graphs have descriptive headings and designations; reports have diagrams and illustrations) though the process of "marrying" the two is not always straightforward, particularly when using automated equipment.

Purpose: Another classification which might be considered during design of a product from a spatial information system is the general purpose or purposes of that product or information. Some of the possible purposes include:

- inventorying
- analyzing
- explaining
- documenting
- designating
- defending
- managing
- forecasting
- monitoring

The design of the product is frequently more effective if the purpose is kept well in mind. For example, if the major purpose is monitoring, the most appropriate product is one which reflects a change over time rather than the production of two documents, each of which shows the situation at a given point in time. This sounds elementary, but the amount of effort that has been spent in trying to compare two similar documents, side by side, to ascertain the differences between them is staggering. A spatial information system should have the capability to generate the "difference."

Other purposes will be most appropriately met by differing formats. The important point to consider, for each product, is how that product will be used.

Audience: A good spatial information system will be capable of producing many sorts of information products at varying levels of detail and sophistication. An additional classification for these products might be the *audience* for whom the product is intended.

Attempts to develop a "super product" should be avoided. As various products evolve, this becomes a strong temptation. Those responsible for system and product design and evolution keep adding more "bells and whistles" which the designers, of course, understand completely. But a person charged with making a decision, who is looking at the product for the first time, may find that an elaborate demonstration interferes with his understanding of--and use of--the information.

One approach designed to avoid this problem is the development of an information product series--several forms of information of similar origin, media, format and purpose. This type of series might show different levels of detail that can be used by anyone exploring all perspectives of an issue. As a product series is used, the first priority should be development of a product appropriate for the needs of the decisionmaker. That product should be supplemented by others of the same general form which provide more detail or additional information. For example, if information on the limits of the 100-year floodplain for a reach of river is needed, the information product should not show the 20-year plain, the 50-year plain, the 200-year plain, the normal yearly range of bodies of water, or the expected annual rainfall, etc. Instead it should clearly show the 100-year floodplain, with a notation that more detailed or sophisticated information is available for other floodplain limits in roughly the same format. If the system can produce a complicated map, it should also have the ability of producing less complicated ones.

Comments on Some Classification Combinations

This discussion has focused on the classification of information products from Spatial Information Systems according to categories of: origin, media, format, purpose and audience. A few comments are now in order regarding some of these classifications and how they may be combined.

Combination #1--Use of Massive Computer Printout

Origin: Automated

Medium: Paper (computer listing) or Microfilm (computer generated)

Format: Character based (usually tables)

Purpose: Any

Audience: Varied

Computers can easily process and print out vast quantities of symbols (numbers, letters, and special characters). As technology advances, computers become more adept at creating drawings, but their leading quality in terms of output lies in the ability to provide data and information at the rate of thousands of lines of characters per minute.

Perhaps the best use of a spatial information system in some applications is to have it print out lists, catalogues or tables of numbers--of which 99 percent are never seen. This type of output can be replaced on a periodic or as-needed basis.

While this approach sounds wasteful, it may be cost effective. Consider the example of a telephone book. Despite duplication, paper, and distribution costs--and the fact that an information service is provided over the phone--it is less costly to organize and provide mostly unwanted information to each customer rather than respond dynamically to his needs for information at particular points in time. On the other hand, the phone company does not provide a list of subscribers for the entire nation. The key point is that the issue of product utility and cost must be looked at in a most comprehensive way--not just in terms of time, materials, or manpower alone.

Combination #2--An Approach to Graphics

Origin: Automated

Media: Paper (computer listing)

Format: Graphic, based on character printing

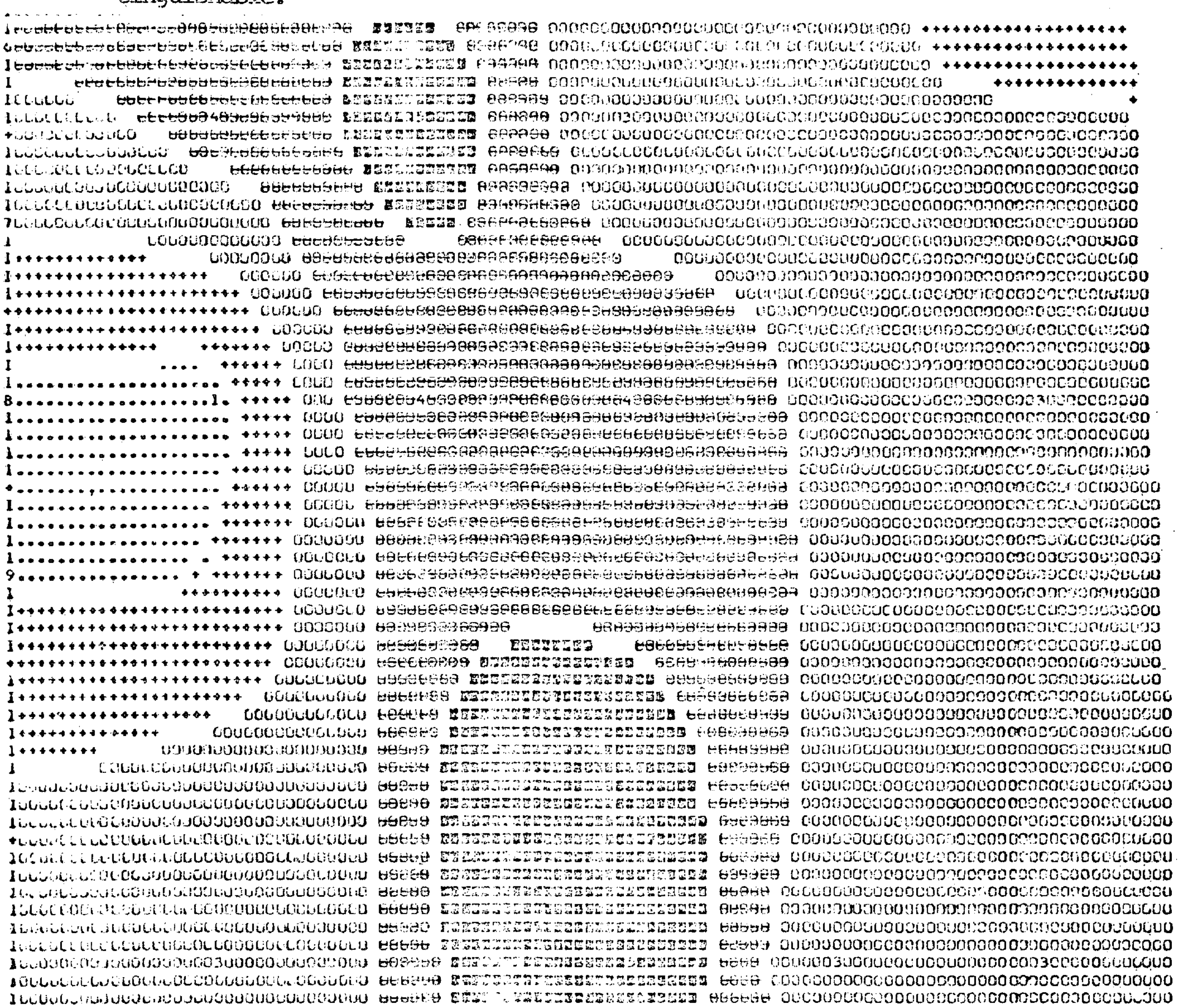
Purpose: Any examination of surface area with general impressions as the goal

Audience: Varied

An interesting way of producing graphic information from a computer makes use of the equipment's capability of rapidly putting characters on paper. The technique is a crude but effective method of printing characters to form a map or chart by varying visual density—darkness and lightness on paper. For example:

```
                 1           2           3           4           5
          ===============================================================
            .........   +++++++++   OOOOOOOOO   888888888   #########
            .........   +++++++++   OOOOOOOOO   888888888   #########
SYMBOLS     ....1....   ++++2++++   OOOO3OOOO   8888488888  ####5####
            .........   +++++++++   OOOOOOOOO   888888888   #########
            .........   +++++++++   OOOOOOOOO   888888888   #########
          ===============================================================
```

Various characters can be used to form small rectangles of different visual density. Using the different densities, computers can produce maps which delineate as many as a score of different conditions. One example might be land use categories: industrial, residential, commercial, transportation, agricultural, etc. Another could show projected population. This form of output is regarded as graphic rather than character in nature because the output is viewed as a map rather than read like text. In fact, such maps are only effective if a viewer is far anough away to make the characters distinguishable.



The advantages of this sort of graphic display, called synagraphic mapping, is that it is flexible and cheap. Conventionally, making a map is quite a project. Maps are usually planned and made far in advance of their use and made to appeal to a wide range of users to help defray the costs of production. They frequently have ten times as much information as any particular user wants. Synagraphic mapping makes possible "quick and dirty" special purpose graphics at a cost which can be measured reasonably in pennies; assuming the data to produce them are available and accessible in a spatial information system, they can be prepared in a matter of hours or minutes.

The disadvantages of synagraphic products are several. For maps on paper there is limited precision--restricted by the numbers of characters per inch (usually 10) of a line printer and the number of lines per inch (usually adjustable to either 6 or 8). The maps are useless when viewed up close; it is best to mount them on a wall, stand back, and fight the urge to get closer in hopes of seeing more detail. Lastly, synagraphic maps are strictly "insight producers": analysis of the information they portray should be based on the basic data which was used to generate the map. (Laboratory for Computer Graphics and Spatial Analysis, 1970)

<u>Combination #3--Arranging Character-Based Information</u>

Origin: Manual or automated

Medium: Any

Format: Character based

Purpose: Any

Audience: Varied, but with the product user also being the product designer

There are many, many formats in which character-based information can occur and you should let your imagination run free when attempting to design the most appropriate one for your uses. One particularly good technique is to sketch out on a paper a format and then an example which you think would serve your needs; then think how you would use it. If you find yourself doing a lot of manual work with the pseudo-output of your spatial information system, maybe you should ask for the information in a different format. For example, suppose some 348 "areas of critical environmental concern" have been nominated and an identification code attached to each; your spatial information system has the information to calculate a factor between 1 and 100 which suggests the degree of danger to which each is subject. The output you envision is a list, in order of identification code, with the "danger factor" printed out adjacent. As you begin to use the output you discover yourself looking through the list to find the area with the highest factor, then the next highest, etc. At this point, while all the information you want is there, it clearly could be in a better format: in order of the danger factor rather than (or in addition to) the identification code order.

Combination #4--Audience and Format

Origin: Manual or Automated

Medium: Any

Format: Discussed

Purpose: Any

Audience: Discussed

Character-based information is the sort that decisionmakers are most used to seeing; graphic information is a form that most professionals who advise decisionmakers deal with in formulating their recommendations.

Some humans, perhaps innately, are better at dealing with graphic information and some with character information. There is also physiological evidence to suggest that the two different types are processed by different hemispheres of the brain. One might draw a parallel with left-hand right-handedness, since the right side of the body is controlled by the left hemisphere of the brain and vice versa.

It is not our purpose to suggest (or deny) that each person has an inherent dominance of ability to process character or graphic information but to point out the danger that an individual may well naturally opt for information in a particular form--just as he might naturally use a screw driver with his right hand--when another form might be more appropriate in helping him gain the insights he needs.

Spatial information systems can provide both character and graphic information and any spatial information system which is designed to provide only one type may be missing a good bet, with the utility of the system itself as the stakes. *Both format types are appropriate.*

Combination #5--Interactive Products vs. Batch Products

Origin: Automated

Medium: Discussed

Format: Any

Purpose: Any

Audience: Discussed

An automated Spatial Information System can be designed to operate in one or both of two modes: interactive or batch. The two modes are classically defined by describing the *way* the product is obtained from the computer. In the interactive mode, a person sits before a device which is connected, perhaps through telephone lines, to a computer some distance away. The device allows the person to transmit information to the computer (usually by pushing buttons on a typewriter-like keyboard) and getting information from the computer (usually in the form of typewritten output or images or characters on a cathode ray tube). The time which elapses between the moment the person (called a system *user)* finishes typing a request into the system and the moment the system responds, called the *response time*, is usually measured in seconds. Thus the user can "converse" with the computer. In *batch* operation, a user prepares a request to the machine (frequently in form of punched cards) and submits the request to a computing center; the results (the product) are produced and available for the user at a later time. The time elapsed between submission of the request and pickup of results is called *turn around time* and is usually measured in hours.

A combination of the two approaches is possible wherein a user submits his request to a computer via a terminal and the computer produces output at the computing center which is available to the user at a later time.

We now make some observations regarding the relative advantages of the two systems:

1) Interactive systems are more appropriate when small amounts of input (parameters) are used to generate small amounts of output. For one thing, computer terminals don't type very quickly both because of the way in which they are made and because the information frequently comes over telephone wires. The more output produced, the longer the user has to sit in front of the terminal.

2) Submitting and picking up jobs from a batch computer is a waste of time for the user. A courier service improves the situation somewhat.

3) For an identical amount of computing, an interactive process is between two and ten times as expensive as a batch operation. In addition to the actual computing and data manipulation charges, there are frequently charges for the amount of time the terminal is connected to the computer, rental charges for use of the telephone lines, etc. On the other hand, there are costs involved in moving cards and paper between the user and the computer in a batch system. Presumably, the computer terminal is closer to the user's home base than is the computer itself.

4) As a generality, electronic things are cheaper than mechanical things--and getting more so. As an example, consider the plethora of hand-held electronic calculators now on the market

and compare their prices against equivalent calculators which *print* results rather than just displaying them. A parallel occurrence is in the computer terminal business where CRT terminals of both the character and graphic type are now available quite inexpensively. But just as with the hand-held calculators, they don't usually produce "hard copy" output. All you can take away from such a terminal is what you remember or what you wrote down; their utility for some applications is clearly limited. Hard copy devices can be added, of course, but the price rises.

5) The ultimate user of an interactive system must have somewhat more knowledge of the protocol for using a computer than must the ultimate user of a batch system, even though, once mastered, it provides them with more control over the results they obtain. The act of a decisionmaker sitting down at a computer terminal is one which cuts out virtually all the "people buffers" between him and the computer. Many decisionmakers will not want to spend the time necessary to either learn or operate the equipment. Also there is a certain element of justified fear involved for even the ablest individual in doing something new with others looking on.

6) Interactive mode usually allows more convenient access to a computer system than does batch mode. On the other hand, the products of a batch system--almost always hard copy--can be moved around more easily than even the portable terminals which are available. And there are times when you will want to have the results of your automated spatial information system appear in places besides their customary home. If this means transporting terminals, searching for extension cords and proper telephone connections, and hoping everything works, the quality of your system in the eyes of the viewers may be impaired rather than enhanced. While we're on the subject we should say that computing in the interactive mode is much more subject to vagaries, such as computer outage, than is batch mode computing. The number of system demonstrations in which "something went wrong" exceeds those in which "everything went right." By comparison, it's hard to fail quite so dramatically with a set of computer listings or drawings packed in a briefcase--unless of course you or an airline loses it.

7) Interactive systems with graphic CRT displays can be very effective in showing dynamically changing pictures. Also the process of developing those pictures can be quite instructive for the user. When looking into the matter of equipment to support the products you want from an automated spatial information system, remember that there are great differences between CRT terminals which display graphics (diagrams, drawings, points, lines, shades, areas) and those which display characters only. True graphic capability is expensive and a terminal which can do it must either be connected with a fast line to a central computer (an ordinary "voice grade" line is probably out for complex applications) and/or

must have a mini-computer attached to the terminal itself.

8) Interactive systems have more prestige than batch ones. But that fades if it turns out that the system won't do the job or costs too much. The major question to be addressed is "How quickly are responses needed to a request?" If the answer is "seconds" or "minutes," an interactive system is the answer. If the answer is longer than that, a batch system is probably more appropriate. All computer systems can be interactive in the sense that you and the computer trade information back and forth over time. The issue is, how much time between trades is "too much." A really good analogy which illustrates the difference between the two modes is communications between two persons. They can talk to each other by phone (interactive) or they can write letters (batch). Each has its advantages and disadvantages, costs and benefits: our message here is that you should examine your needs (and what facilities are available) rather than just assuming that one mode or the other is the way to go.

Some Observations about Products

1) Much of this section has addressed the matter of design and development of products to meet the needs of decisionmakers: managers and planners. But we have not mentioned a spatial information system product of underlying but vital importance: the geographic base map. This is a cartiographically or photographically produced product of, usually, great accuracy, high precision and great detail to which all the other products of the spatial information system can be referenced. Its primary use is for human visual examination although it may well serve as the basis for input to the manual or automated digital spatial information system. To attempt to build a spatial information system without first developing (or otherwise obtaining) a geographic base map is sheer folly.

   In addition to underpinning the entire system, the base map can perform another vital function. It can serve as an important "first product"--useful to a wide variety of state agencies. We say "vital" because it usually takes several years to build an extensive operational-status spatial information system. In this country governmental personnel in high level executive posts are "reevaluated" every two to six years; such a time frame can prove devastating to an eight year project. Thus, it is important that the spatial information system development process show some progress along the way; the base map, thought of as a product and marketed as such, is a good nominee.

2) In the design of a product there should be a balance between simplicity and generality. In one sense the best product is one which speaks directly to the decisionmaker, respecting his particular abilities, relating to the issue he is dealing with. On the

other hand, it is nice to have a product of such good design that it can serve the decisionmaker, his advisor, those in other areas, perhaps the public and the courts. Map makers, of course, are well aware of this design problem. A map's usefulness is increased by adding a new type of information and decreased at the same time because the map becomes more cluttered.

Having the data to support spatial information system products in machine readable, digital form allows greater flexibility in the production of products than do normal cartiographic techniques. It should be possible to develop products in short periods of time for particular uses which are unencumbered by extraneous information. The key to such a process is *modularity*--the development of sets of information which can be combined in meaningful ways to produce a single product. A physical analogy of an *information module* is a brick--a standard entity which can be combined with others to produce unique products.

3) Product design is an art which marries what is possible with what is needed. Many factors go into successful design:

Examination -- of products from other systems

Innovation -- the ability to conceive of more meaningful ways to display information within the constraints of the devices which put the information together

Refinement -- of products which the spatial information system is already producing; obtaining and heeding feedback from users of the product

Knowledge -- of what data are required (and the characteristics of those data) to produce the needed information

Lack of Bias -- towards either character-based or graphic information; an ability to provide information in the best format for the given customer.

4) One current sticky wicket is the issue of whether to base the output of a spatial information system on the metric or English system of units. If the system designers have been reading the signs, the basic inputs and internal manipulations of the system will be metric. What shows up on the product will have to take into account both the nature of the audience and its desire to move towards use of the metric system. If English units are to be primary on output, then some provision for

switching later without disrupting the entire operation must be thought out in advance. Avoid cluttering products with both measuring systems. One approach might be found in the product series concept; make two equivalent products, one with English units, the other with metric. There must be obvious and absolute differentiation between the two.

5) We have implied from the outset that the reason to have a spatial information system was to either

(a) provide new information
(b) provide information in new forms.

Developers of spatial information systems sometimes become so caught up in this task that they neglect a second but vital component of the operation: providing explanatory, documenting, context setting information about the primary information. We call such information, for want of a better word, *defining* information. A partial list of defining information for a report or document might include:

- A title
- A descriptive paragraph on the content of the document and how it is to be used;
- The geographic area covered;
- The date the information was produced;
- Identifiers which allow the user to determine the defining information <u>about the data</u> which support the information in the report;
- Statements about the precision of the information in the report;
- Estimates of the accuracy of the information in the report;
- The variables which went into the production of the report;
- A name and phone number of a person (or agency) to contact for information about the report;
- All of the parameters that were supplied to the user in the production of the report;
- Any warnings to users;
- Identification of agencies and individuals responsible for the report.

Not all of this information need appear in the same format in the same place. In an automated system some of it will be generated by the computer and appear on the printout: date, data identifiers, parameters, precision and accuracy information, etc. Various descriptive information might better be printed separately and attached to the computer produced report. Regardless of the methods of production or dissemination, a product from a spatial information system should be a complete package.

It may be determined that each user of a spatial information system should be given a user's manual of the system. Such a manual could set the context of the entire system and then describe each product series. Such a manual should be loose-leaf and modular; and the updating scheme should be thought out carefully. When defining information about a report is contained in the user's manual rather than in the product itself, the product must contain references to the user's manual; the loss of the link between the report and its defining information can prevent acceptance and use of the system.

One of the values of a spatial information system is its capability to combine different types of information which have the same geographic base. For example, a user might need a map displaying a single variable derived from a combination of soil type, bedrock type and depth to bedrock. An important aspect of the defining information of a report combining these three variables is the confidence one can place in the accuracy of the resultant information. Each of the constituent individual variables is stored in the data base and each has its own characteristics of precision and accuracy--measured in terms of geographical coordinates and the values of the variable. Therefore, just as the values of the three individual variables are combined to produce a single variable, *the precision and accuracy attributes of these variables should be combined*--according to appropriate numerical techniques--to produce statements about the accuracy of the resultant report. These statements of accuracy should be produced as part of the resultant report.

This process is not always easy, nor are the results always encouraging. For example, in a study done by the Australian Commonwealth Scientific Industrial Research Organization, involving three variables, an analysis was made of the output. When particular points on the Earth's surface were picked out, it was found that at least one of the constituent variables was incorrect more than 60 percent of the time. The implications for the accuracy of the combined report are obvious. (Dangermond, 1973)

6) Several other factors--including size, scale, resolution, appearance, readability and shape--can affect the utility of an information product. The first three will be discussed individually; the others will be found within the context of comments in other parts of this book.

Size: The distance--in centimeters or inches--between the pair of points most distant from each other on the product. (There might be more than one pair of points; for a rectangular map, there would be two pairs; for a circular map, an infinite number of pairs would exist).

Scale: A ratio of distance on the product to actual distance on the ground measured in the same units. Usually expressed as 1:X where X is a number greater than 1. An example is a map with a scale of 1:24,000, meaning one inch of the product is equal to 24,000 inches (or 2,000 feet) on the ground. A confusing bit of terminology is associated with use of the term "large scale maps." One not conversant with map terminology must be cautious, for details on a 24,000 scale map actually would appear larger than the same details on a 100,000 scale map, though the numbers might seem to indicate just the opposite. The smaller the number, the larger the scale and the greater the detail.

Resolution: Basically, the smallest length in ground units which can be resolved by looking at the product. For example, what is the diameter of the smallest object which can be seen in an aerial photograph. Clearly, the answer depends on several things beside the diameter of the object. It involves the reflectance of the object compared with the surrounding ground, the quality of the vision of the person looking at the photo, and the scale of the photo. An 8x10 photo of Arizona might allow only an object the size of Phoenix to be visible. Through enlargement of the same photo, however, it might be possible to increase the resolution so that an object 100 feet across could be identified. If further enlargment--no matter how extensive--did not allow identification of objects with diameters smaller than 100 feet, then the maximum resolution of the photo is said to be 100 feet. Thus, it is obvious that resolution and scale are closely linked--the larger the scale, the greater the resolution--up to a certain limit. Beyond that limit, no further information can be obtained from the product simply by enlarging the scale.

If a specific ground area is to be covered, designers must then weigh the relative factors of size, scale, and resolution to determine the most appropriate method of producing an information product. Too often these determinations are made without sufficient thought, or are influenced by habit and conference room table size. The issue of appropriate scale must be considered early in the process because some spatial information system products utilize overlays and base maps of other materials to make them meaningful. Obviously, a nearly exact physical match must occur further; the size, scale, and resolution of both base maps and overlayed products must be appropriate.

It is worth mentioning here that reproductions of map output, from any source, are not always the same size as the original--and hence not the same scale as the original. Unfortunately, the statement regarding scale that is printed on the map is usually reproduced along with everything else, creating a built-in lie.

It is not only graphic products which must get attention in terms of their visual utility. Factors such as size, shape and format, appearance and readability are important in character-based output as well. Again, thought should be given not only to the product itself but to subsequent reproductions of it by photographic or other means. (A good example of a frequent "miss" in this area is taking a 35 mm slide of a full sheet of computer output. If you had a dollar for every time a speaker at a meeting has apologetically said "Now, I'm afraid you can't read this" you could finance a medium sized computer system.)

7) A person familiar with the product (including the assumptions underlying it and other products which might be useful to the decisionmakers) should be present when the product is used. People charged with making decisions have a way of asking questions no one thought they would ask. Anyone who presumes to provide them with new information in new formats had best be ready.

The person charged with the responsibility of understanding and explaining a document is also in an ideal position to recommend changes in the document's structure or information content based on conversation with the users of the product. The dissemination of a product containing information is very much a two-way street and relies on user feedback for its successful continuation.

User needs change, user needs are not correctly perceived by product designers...many factors suggest that a continuing dialogue between the providers and users of information products must exist.

It may be that, instead of having a person assigned to a particular set of products as the interface between the decisionmaker and the product, personnel will be assigned as liaison to various departments using the products. Whichever scheme is chosen, those personnel charged with the function of interfacing products with decisionmakers should meet among themselves regularly to aid in improving the effectiveness of the spatial information system operation.

8) If a product is generated by a computer, at least two options exist for being able to use the information from that product in the future. First, if a computer is fed precisely the same inputs and operates under precisely the same conditions, it will produce precisely the same outputs. Thus, it is possible to recreate the output at a later time. On the other hand, the fact that a computer produced product means that the capability exists to easily record that product in an electronic, nonvisual, way

either for future visual production of the product or for use of the product as part of the data base. For example, if a flood plain map is produced from other more basic data, it might be reasonable to develop a new variable in the data base which depicted the flood plain. This could be matched against future building requests. Thus, the information product from one process can serve as the data input to another.

SUMMARY

The reader can see that the number and diversity of potential information products from a spatial information system is almost unlimited. These products, however, are useless if they don't fill a need or if they are inappropriate for their intended audience--as with the photos for the judge with the seeing eye dog. Therefore, any design of an information product must proceed from an enlightened view of the data used to support it, as well as a clear understanding of the needs of decisionmakers or administrators who will be using it. (Farman and Nivergelt, 1969; Voelker and Meyers, 1972)

PART E

Data: Raw Material

"Garbage in, garbage out"--An often quoted, but seldom heeded, admonition in the computing world.

Data form the basis of a spatial information system or an automated spatial information system. These systems are referred to as being "data driven" to emphasize the importance adequate data play in their operation. The product of a manual or automated spatial information system is the most important contributor to its utility; the data are the chief ingredient of that product. The single message emphasized by this section is that any determination of what data are needed and what the characteristics of those data should be, comes after a very careful look at what sorts of information products are required for specific decisionmaking. The products, one would hope, are developed to satisfy the needs discussed in Part C.

Determining what data are needed is not an easy process. It requires the concentrated effort of experts--from the decisionmakers who will use the ultimately produced information to the scientist who gathers and analyzes the data. The ideal order of matching data to needs is from the specification of the information product back to the data gathering—that is, in the direction opposite from the one in which the process of producing the information takes place. (Brady & Branscomb, 1972)

The fact that a lot of already collected data exists will influence not only the process of turning those data into information but will influence the types of information produced as well. But to allow the fact that some inappropriate data are at hand to dictate the output of a spatial information system reminds us of the man who, one evening, lost a ring on the north side of a street but searched for it on the south side because "the light was better."

Steps in Developing the Data Base

(1) Determine what types of data are needed to produce the product(s).

(2) Determine what characteristics of those data are necessary to provide the accuracy, timeliness, coverage, etc. demanded by the product; set priorities.

(3) Make some preliminary studies to determine that the data and characteristics specified will produce the information wanted.

(4) Begin a data acquisition effort--search for already-collected data which meet specifications, or begin a sub-area data collection effort.

(5) Put data acquired into proper form (reformat, or encode it) for inclusion in the spatial information system data base.

(6) Check accuracy of each step of the collection process; also check the first form of the data against the form in the spatial information system.

(7) Repeat steps 4, 5, and 6 for the complete set of data for the base.

(8) Employ techniques for monitoring and updating of the data base.

We now look at these steps one at a time:

1. Determine what types of data are needed for the information product(s).

This assumes that you have determined the needs of the decisionmaking apparatus and, further, that you can identify the sort of information which will satisfy those needs.

The most important component in this step is to have people involved who (a) understand both the information required (and how it is to be ultimately used), (b) the characteristics of data which might be used to generate the information, and, (c) the manipulation of the data necessary to produce the information.

At this early stage, it is wise to consider alternative and innovative ways of getting to the same information. For example, if the information required is a delineation of areas of potential high soil erosion, then calculating the potential soil loss might be produced using the universal soil loss formula (Wischmeier & Smith, 1965) and spatial data including rainfall, soil erodability, slope length and gradient, and vegetative cover. On the other hand, it might be produced by interpreting aerial photography for existing erosion conditions. Many projects which get into trouble at this stage do so probably because communications with the analysis and decisionmaking group ceased after the initial contact. Problems are constantly changing in both importance and type. Thus, to be most responsive, the data support sector of a decisionmaking process must have its roots not in the data collection area, but rather, in the analysis and decisionmaking area.

2. Once the basic types of data required have been identified, more thought must be given to the characteristics of the data to be acquired.

A very comprehensive discussion of data characteristics appears in the Department of Interior Document Information/Data Handling: A Guidebook for the Development of State Programs, July 1975 available from the National Technical Information Service.

In determining the characteristics of the data needed, several fundamental questions should be asked:

What geographic area is involved? What geographic identifiers are necessary for use of the data? With what accuracy must the coordinates be known? Are the values of the data "continuous" (like elevations above sea level) or "discrete" (classifications of land cover)? How frequently do data values change? What causes these changes? Are the most basic data types in use or can other data be derived from more basic sources? If the latter, what are the advantages and costs in using the most basic information available? What degree of detail is required? When the detail level desired is "multiplied" by the area involved, how many data must be dealt with? How sensitive to errors in the data is the process which is used to get information products from the data?

3. Make some preliminary studies to determine that the data and characteristics specified will produce the information wanted.

How this task is done depends greatly on what is available. If an operational map overlay or computer based spatial information system exists and new data to support a new product are being added, the best course might be to generate some typical sub-area data to try out the process. If the spatial information system does not exist but is being built initially to produce the product, the issue of preliminary testing of the data product relationship must be attacked differently. Perhaps an analysis of your plans could be contracted to a consulting firm for checking. However it is done, someone other than the originators of the techniques for development of information from data should independently examine the projected course of action.

4. Begin the data acquisition effort.

So far we have described a rather idealized process for the formation of a portion of a data base for a spatial information system. We think the idealized approach is worth sticking to. Too many times the existence of some collected data not only dictates the process used to manipulate them but also the kinds of products which get produced. It often turns out that when the cost of conversion of already collected data is counted, the error rate discovered, and the lack of suitability of the data for the task at hand realized, more money and time will have been spent than if an original data collection effort were begun. And yet, it is unreasonable not to make an examination of existing data sources, after you know what you want, to see if, considering the millions spent on data collection in this country, there are some which will meet your needs.

(a) A search for relevant data will not prove easy. It is the type of frustrating undertaking which one never really knows when to surrender on; how long do you keep looking before you elect another route. The process of finding existing data sources is not aided by any sort of comprehensive lists, catalogues or directories at either the Federal level or among most states. A common problem is that very few people seem to have both the depth of understanding required to manipulate data into information in particular areas and also have the overall view of how to collect the data which could be relevant to the decisionmaking process.

A real search, therefore, should be undertaken and it should look widely, not eschewing any possible source of data. Interviewing of individuals in various agencies is probably as profitable as searches through documents; interviews may produce more up-to-date information about data sources or data collection efforts.

There is no dearth of data in this country, spatial or otherwise. But there are three major problems with existing data:

(1) The data files themselves are spatially distributed, hither and yon, in offices and computing centers, in desk drawers and filing cabinets. Perhaps the first task in developing data for a specific geographic area should be a list that includes data sources, characteristics and owners.

(2) The data are not in a common format. Granted, different sorts of data should be presented in different form because of their inherent characteristics and uses. But the variability vastly exceeds the requirements for different formats.

(3) Already existing data are getting older and less correct every day. Barring some catastrophic event, such as nuclear attack, the accuracy of the data will decay slowly over time.

A method for assessing the correctness of data after a length of time might be borrowed from the concept in physics of a radioactive half life period. Such a period, measured in time units (from millionths of a second to years to mellinia) and different for each radioactive substance, is the length of time required for half the weight of the substance to have decayed into something else. In general form this idea could have a parallel with "correctness of a set of data" as the variable instead of mass of material. The correctness of spatially distributed data of a given type, say land use, decays at different rates depending, as one might imagine, on its location. A greater rate of decay would be expected adjacent to urban areas than distant from them. In any event, the age of the data used is one of its most important characteristics.

Assuming a set of already collected data has been found which approximately meets the specifications, the data should be carefully analyzed according to a number of characteristics:

- Can the data be used directly or must they be manipulated before they can be used in analysis?

- Are the data the most specific and detailed available? When accuracy is critical, is a version printed on paper being used when a more stable version on non-shrinking, non-stretching mylar is available?

- Is the resolution of the data sufficient to fill information needs?

- Are data mapped at an appropriate scale for the resolution required?

- In what geographic coordinate system are the data recorded? What complications will occur in converting the data if conversion becomes necessary? Will accuracy or resolution be lost in the process?

- What process was used to collect the data? Do statements about the precision and accuracy of the data accompany the set?

- Are the data uniform? Is the medium on which they are recorded also uniform and free from the kind of distortion found in some aerial photos.

- Are the data truly available? Who owns them? Are they in the public domain? Can "originals" be obtained, or only copies; what information is lost in the copying process?

- Are there administrative obstacles precluding use of the data? Are they subject to provisions of confidentiality? Are they classified by the military?

- How much time is required to obtain the data? How much time must be allowed to reformat or encode them?

- Will information updates be available from the same source? If not, will new updates, possibly from different processes, mesh with existing data?

- When all considerations are combined, what will the data cost?

(b) If you can't find data sets which meet your specifications--or even if you can--you may embark on a data collection effort. In many ways, if data which approximately meet your specifications are available, the issue of whether to use them or collect your own is much like the issue of whether to buy a used or new car. There are advantages, disadvantages and uncertainties associated with both courses of action. The decision can become very much the classic avoidance-avoidance conflict that college sophomores learn about in psychology courses: the more you look at other people's data for your requirements, the more you want to collect your own; the more you examine what you have to go through to collect your own, the more attractive the existing data seem.

If you decide to collect data anew many of the concerns for characteristics still apply but the question changes, from "Do these data have the properties I want?" to "How do I construct a process to produce the data and characteristics I want?"

Probably the best advice to anyone planning a large data collection effort is to start slowly... and carefully. In fact, with all operations involving a data handling program, one should probably use a "10% planning rule." This rule says that if X dollars is to be spent over a period of time, then 10% X dollars should be spent over the previous period on the same subject. For example, if one million dollars is to be spent on spatial information system development in a year's period, $100,000 should have been spent in the year before for planning, analysis, and testing. And, by extension, $10,000 should have been spent the previous year before to determine how to spend the $100,000.

The 10% planning rule suggests, then, that a small but substantial and representative amount of data be collected, encoded and validated before the major data collection effort gets under way.

The process of data collection must be carefully planned and executed. It is possible to spend a lot of money at it and wind up with nothing very useful. Among the points to consider are:

1) The work may well be contracted out. Be sure that all understandings with the contracting firm are both written down and completely comprehended by both parties.

2) There aren't very many firms in the country that do good intermediate and high altitude orthophoto work. Those that exist are scheduled for months or years in advance.

3) Rigid timetables for collection of data about the environment cannot be followed. Clouds form, trees get leaves, airplanes malfunction, the ground gets wet. Timetables must be based on probabilities.

(c) A rather special sort of data is available to states which fits neither the "find someone else's" or "collect your own" situations. These are data which are collected in an ongoing fashion by satellite or high altitude aircraft and made available by the Federal government. These data primarily depict land cover (from which, in many instances, land use may be determined). The use of data collected in this way has a number of advantages. Among them: (1) the data may be obtained in already digitized form on computer tapes, (2) updating takes place on a periodic basis, (3) a large portion of the cost is borne by the U.S. Government, and (4) computer programs are available to manipulate these data.

There are two basic programs under which such data may be obtained: (1) The Land Use Data and Analysis (LUDA) program of the U.S. Geological Survey, and (2) The Earth Resources Data Analysis System (ERDAS) of the National Aeronautics and Space Administration.

The choice of which group to get involved with, if either, is one that requires a great deal of study and no small amount of technical expertise. Among those multi-state organizations which have been involved in such study are the National Conference of State Legislatures headquartered in Denver, Colorado; The Council of State Governments headquartered in Lexington, Kentucky; and the Southern Growth Policies Board headquartered in Research Triangle Park, North Carolina.

Basically the LUDA program consists of extensive map and tape products depicting Land Use/Land Cover in an already defined (for the most part) categorization scheme. The LUDA system produces primarily a comprehensive mapping at a scale of 1:250,000 on the UTM grid. The potential resolution of the system is in the 10 to 40 acre range.

For a state to avail itself of the LUDA mapping program it enters into a 50-50 cost sharing arrangement with the USGS; the cost of compiling LUDA products is about $1.30 per square mile without either flying costs (if any) or photo-reproduction costs being included. Updating might be expected every five years.

The ERDAS program of NASA also uses both LANDSAT satellite and high altitude aircraft data. Here, however, the user has the option--and the headache--of deriving his own categorization scheme or choosing among those suggested by the agency or commercial firms which market the products. The data which come from NASA are much less predigested, which puts added responsibility and capability in the hands of system developers. While the ERDAS system can also produce color coded maps--seemingly at about the same cost as LUDA--the emphasis is more on the discrete symbols representing the digital input from the multi-spectral scanners in the satellite or aircraft. The resolution of the data is based on a satellite picture element (pixel) of about one acre. Updating could occur more often than monthly if desired and if the clouds cooperate. Three computer tapes can cover a state; the UTM grid is used.

5. <u>Put the data acquired into proper form for inclusion in the spatial information system data base.</u>

This process will be discussed in more detail in the next Part.

Basically, the process of encoding the data means transforming it from the basic form in which it is collected (or acquired if already collected data are used) into the symbolic or graphic form required by the spatial information system. The process depends on the types of data, the precisions required, the equipment available, the scheme used to represent the data in computer memory (called the <u>storage paradigm</u>) and other factors

6. <u>Check the accuracy of each step of the collecting or reformating process; also check the first form of the data against the form in the spatial information system.</u>

Two elements must be constantly monitored: (a) the process of collecting and reformating the data, and (b) the quality of the data themselves. Perhaps the most important statement that can be made about this "checking" process is that it be accomplished by someone other than the person or group doing the data collection.

Such independent checking has many virtues: it provides for a more objective view by those doing the checking; it assures that the checking activity is a project <u>in itself</u> and not just an adjunct to the data collection effort; it reduces the temptation to use the same techniques to check the data as are used to develop the data, and others.

There must be more to the checking process than simply ascertaining and reporting error rates. An understanding of why errors occur must be developed. If the encoded value for evaluation at a certain point is 1023 feet and a checker with an altimeter set on the spot finds 999 feet, what happened? Was the problem one in measuring altitude? Are the positional coordinates off? Is there some systematic or random error in the encoding process or equipment?

It is vital to understand that <u>all large data bases contain errors</u>. If a variable in a data base is a continuous quantity, such as elevation, there will be values outside the established accuracy standards. If the base is one of classifications, such as land use activity, some uses will be misclassified. If the base is geographically referenced, there will be disagreements of actual locations between points of the earth's surface and where the system has them located. The purpose of validating data is to develop an understanding of how great these error rates are and, if they are too great, take steps to reduce them.

7. <u>Repeat steps 4, 5, and 6 for the complete set of data for the base.</u>

Realize, however, that the data base will be a growing, evolving thing, supplying useful information to decisionmakers into the next century. These steps are simply the first ones. By the time the pilot data have been satisfactorily collected or acquired, encoded, and validated, the data base developers should have a firm grasp on the associated problems, costs and techniques. There should be some serious thought on the differences between the pilot project and the major data-gathering effort.

There should be no letup in the testing of data as they come in and are encoded. And if you really want to put your data collection techniques on the line, recollect some data from the pilot area and compare it against that originally collected. The results of that may be very instructive, if disheartening.

One of the worst losses at this point can be of key personnel, now much more valuable than when the pilot data collection began. Their importance to the success of the system should be recognized and appropriately compensated, if possible.

8. Employ techniques for monitoring and updating the data base.

Even as the major data base collection effort is going on, the world will be changing and new problems will be appearing; updating must be a constant activity to keep the data base reasonably current. (Barrett, 1969; Teitz, 1966)

PART F

Ingredients of a Spatial Information System

What is the process which "churns" data into products. What is the mechanism which fills the needs for information at the Federal, state, and local level to improve the decisions about land and resource use--decisions which will affect our lives and our children's lives. We've given a name to it: spatial information system. In Part A, we described it in general terms and put it in context. Part B suggested some uses for it. Part C indicated how one might assess a need for it. In Parts D and E we talked about its output (products) and its input (data). Now finally, we identify some of the components of the mechanism itself, some facets of the process which make it all happen.

In the present section we present discussions of components of a spatial information system rather than discussions of how to put one together. Another document, available from the same source as this one, called Avoiding System Failure; Approaches to Integrity and Utility, suggests ways to avoid error when building a system. This section is rather more like a set of architect's drawings which show details of the structure rather than a manual on how to assemble it. There are many ways to look at the ingredients of a spatial information system. Those we have chosen are:

- Impetus for Development: Focused and Panoramic
- Time and Money
- System Development: A Set of Four Steps
- People: Managers, Developers, Experts, and Users
- System Design: The Elements
- Equipment: The Gadgets
- The Procedures: For People, for Machines

Impetus for Development: Focused and Panoramic

There has to be a push for the development of a spatial information system from somewhere. Someone with large responsibility has to have a relatively long range problem to solve; also, he must believe that a portion of the solution will come from information generated by a system which can process spatial data. In the paper Avoiding System Failure, there is a detailed discussion of how lack of commitment can scuttle a spatial information system project, either initially or after work is well underway.

One wants a spatial information system which has both current utility and the generality required for growth.

One key to the successful development of such a system is to focus development around a relatively high priority problem (or a set of them) and at the same time take a broad view of the entire spatial-data issue. It is important not to close off options which would let the system grow over the years to the point where it could deal with spatial data in any form and interface that with other types of data. To ask a program manager to generalize the capabilities of the tool he is building for a specific purpose is not easy, especially when deadlines become tight and money short, but doing so is the key to avoiding a plethora of non-standard, non-communicating spatial information systems in the future.

Time and Money

A state cannot frivolously take up the task of development. The costs are high, although they appear miniscule in terms of the potential benefits. Costs must be measured in terms of millions of dollars—perhaps up to twenty.

Perhaps more important than monetary costs are time expenditures. For one thing, the passage of time is a more obvious phenomenon than the transfer of money. For another, in some endeavors an increase in the financial expenditure will not result in a decrease in the amount of time required to produce a quality product. Even the well honored bureaucratic maxim, "There's never time to do it right but always time to do it over," probably isn't applicable. A geographic or land information system which fails will probably be the last one in the vicinity for at least a couple of generations of state administrations.

Figure on five to eight years for development of a garden-variety automated spatial information system. Usefulness of some of the interim developments, such as base maps or photos, might begin at the end of three years. For a fully operational system serving the state, regional, county, city and Federal level—including advertising, marketing and familiarization—plan optimistically on a decade.

On the other hand, a decade doesn't seem too long, considering that the uses to which the land is to be put will probably affect the citizenry for ten to one hundred decades. In England, 999 year leases are given—and some of them are now coming up for renewal—which implies that some relatively long range plans do get made for land. There are many problems today, now, which could benefit from a spatial information system. For the most part, we do not have available the systems we would like to help us deal with them. But there will also be problems to solve in ten years and we do have the option of dealing with them with new tools if we start now.

System Development: A Set of Four Steps

One ingredient for successful development of a spatial information system is a plan for the activities which produce it. Although the development process is continuous, it is possible to look at it in stages as well—provided there is an understanding that the boundaries between stages are not rigid.

Four stages—or processes—which encompass both the assembly and operation of a spatial information system will now be discussed. These stages involve the conception, design, construction, and operation of a typical spatial system.

Conception -- the process which leads to the decision to build a spatial information system. It solidifies the impetus for development; defines the balance between focus on particular issues and the generalities of the system; defines the scope of the system; identifies major participants (sponsors, designers, constructors, users); determines general philosophy; and assures commitment to the project (political, administrative, monetary).

Design -- the process of translating the general directives produced by the previous phase into a detailed and precise description of the spatial information system; the process takes place with the resources provided by the previous phase and within constraints of time, money, talent, and overall objectives.

Construction -- the process of building the system according to the prescriptions of the design phase. Data are collected and reformated; procedures for operation are developed; and if the system is automated, computer programs are written and the entire system is tested.

Operation -- the process of making the spatial information system available to the user/client for decision-making. Operation is considered a part of development, rather than a separate activity, because the system is constantly changing as it is used. Operation includes day-to-day management, user/client relations, monitoring, and obtaining user/client feedback, new problem applications, data base update and augmentation, system maintenance, charging for services, etc.

<u>The People</u>

Conception -- In the conception phase are elected officials and their designated administrators who must provide the go ahead for the development of a system as large and expensive as a generalized spatial information system must be. It is important to understand both their backgrounds, the constraints under which they operate, and that they must deal with a myriad of issues. Information which comes to them, whether <u>from</u> a spatial information system or <u>about</u> the development of a spatial information system, must be clear and concise.

Another group of people in the conception phase are the backers or sponsors of the development effort. They may be the same as the elected officials or they may not be. (In fact, throughout this discussion the reader should be aware that, although we identify different types or groups of participants in a spatial information system development project, many of them may be the same people, wearing "different hats" at different times. It is still useful to describe them by role as we are doing.) The sponsors are making an investment in the system and they expect something from that investment. Most likely, although such a system has capabilities for doing research, what is expected is a product which can aid in decision-making. The role of the sponsor and his view of the objectives of the system should be carefully examined and understood. The sponsor must spend much money and wait for quite a time to see results; his level of commitment must be high and ongoing. One of the easiest ways to fail with a spatial information system is to oversell the sponsor by implying system capabilities and timetables which are overly optimistic.

The key managers of the development process will probably be identified during the conception phase. The plural, "managers", is used because no one is capable of managing the entire show with the depth of understanding across the breadth of issues which must be faced. The management team must have strong administrative capabilities, appreciation for the problems that the spatial information system hopes to help solve, a comprehension of the balance between the art of planning and the several sciences which support it, and the technical understanding of the complex process which begins determining needs for information and ends with the use of products produced to fill those needs.

Finally, in the conception phase, are the potential users. Having them involved at the initial stage is central to the success of the project. Some of them may be sponsors, elected officials, or managers as described above; many of them will not be; but their inputs are still vital.

Design — The designers have the task of taking the general desire of the system conceivers, together with many constraints, and producing a blueprint for the system. They, more than anyone else, must understand the entire process and it is on their shoulders that the utility and longevity of the system rests. While there are recognized patterns of the design process, there is no formula for good design. Our advice is to find the best and most experienced people available and let them go to work. Additional funds spent on good design can produce savings in the construction and operation phases.

This is not to imply that the design team should become a sacred cow. Its work should be carefully monitored by the managers of the development effort, both to be certain that the design is proceeding along lines consistent with the objectives, and to insure technical quality. Designers are creative people who are capable of (1) producing innovative approaches and also (2) going off on tangents. Knowing the difference is the managing team's responsibility.

It is probably a mistake to contract out the design portion of a spatial information system. The designers should be those who have an ongoing commitment to the task and who will be around to install the inevitable modifications to the system.

Construction — Three primary tasks must be done during the construction phase: define procedures, collect data, and perhaps write programs. One of the stickiest problems is integrating these activities, which will go on simultaneously, so that the resulting endpoints are compatible.

The development of procedures—guidebooks, forms, organizational hierarchy—is probably best done by the managers of the entire development project. In this endeavor they should have some help from the user community and people who are experts in continuous, stable operations. There is quite a difference between project or development work and ongoing service work. They require different mental and emotional approaches not usually found in the same individual.

Data collectors and data converters may come in many different guises just as do the data themselves. Doubtless some of this work will be contracted out. The system designers must have drawn tight specifications for the quality (precision, accuracy, timeliness, etc.) of the data. Everything must be written down and also understood. Pointing out the fine print to a contractor, after half a million has been spent gathering data which won't work, doesn't benefit anyone. Concrete is being poured during this process and the monitoring must therefore be close to perfect. The collection of data in a fairly large pilot is worth it--if only to determine how to write the specifications for the larger data collection effort.

Data conversion--for example, extracting numbers and symbols from maps through a process called digitization--must also be carefully monitored and checked, whether the work is done in-house or contracted out.

A third group of people upon whom the success of an automated spatial information system depends is composed of computer programmers and their managers. Getting computers programmed correctly, the first time, is a real trick. A discussion of the process is deferred to the discussion on "Procedures" at the end of this section.

Operation — The most important people in the operation phase of a spatial information system are the users or clients. There is no reason to develop a spatial information system unless its products are used.

There is simply no such thing as a static operational phase for a spatial information system. The user community is dynamic, changing, faced with new problems, becoming more educated and sophisticated, enlarging as the word about the spatial information system spreads. Users are also often wrong about what their real needs are--a fact which comes out after the product they specified turns out to be inappropriate. All of this implies that the operation phase of a spatial information system must be flexible.

Thus, the interface between the spatial information system and its users must be of great concern to the managers. Those staffing the interface should have several qualifications and abilities:

(1) An interest in and some understanding of the problems the users are trying to solve;
(2) An understanding of the assumptions underlying the system;
(3) An understanding of the products of the system.

The extent to which the system is serving the user community should be constantly monitored. Feedback from users should be obtained in at least two ways: (1) the interfacing staff should be sensitive to complaints or comments or suggestions regarding system operation and products, and (2) a periodic polling of users, usually with a written form or carefully designed interview. The results of both approaches should be written down, kept, and carefully reviewed from time to time. Outlandish user requests one year may not seem so far out the next. As we illustrated with the diagram at the beginning of Part C, the capabilities of the spatial information system will create new "needs" in the user community. The managers of the spatial information system must be perceptive of and receptive to those needs.

A spatial information system will not "self-market". The operations staff of the spatial information system must contain a marketing component which may or may not be part of the interface staff. There is a great deal of inertia which will prevent governments and their offices from making use of new and better information unless specific action is taken to make them aware of the advantages. The marketers should also be on the alert for hints from potential users which might imply new areas of need that the spatial information system could fulfill.

Finally, to keep a spatial information system working requires, in smaller degrees, all of the types of people found in the first three phases. There must be sponsors of the operation. Even if these sponsors are, for the most part, users who are paying for the system through fees, there will probably still be additions to the system which the fees won't cover. The design of the system will be modified time and again, usually in small ways. But any changes must be made with their effect on the total system well understood. Thus, retaining some of the senior system design staff is vital. Design changes need to be implemented so the data collectors and programmers should be available. Again, if the people who did the original work are around, the advantage is considerable, provided they documented what they did so that they can recall it with reasonable effort. If it isn't documented and they aren't around, you might as well start over.

System Design: The Elements

What follows here is a simple list of things that designers of a spatial information system should generally think about. Many of the "elements" mentioned are interrelated, but these interrelationships are not dealt with here. The following discussion centers around the question of "what needs to be done" rather than "how to do it." The reader interested in details of system design may refer to other documents as indicated in the Resources.

A Storage Paradigm:

This discussion pertains to any system in which information about the environment is stored in discrete symbols (numbers, letters, special characters). How can the continuum of the environment be represented in the data base of a digital computer system? There are at least three answers: idealization, aggregation, and probabilization.

In idealization, easily manipulated symbols are substituted for actual, three-dimensional, real world objects. For example, an oil well can be represented by a point, or a gas transmission system can be represented by a sequence of straight lines.

In aggregation, entities having somewhat similar characteristics are put together. For example, saying a segment of a county has X acres on which cotton is grown and Y acres where tobacco is grown is a statement of aggregation. Information about where respective acreages of crops are located is not in the statement.

In probabilization or assumption, data with an assumed degree of accuracy are interpolated or extrapolated to obtain new information that is assumed to be correct. A point on a topographic map midway between the 1250' and 1260' elevation contours may be estimated to be located at roughly the 1255' level. (To get a better estimate, one might also consider the 1240' and 1270' contours.) In any event, the elevation of such a point is known to be not less than 1250' nor more than 1260'. Thus, in some cases, there are bounds on the error introduced by the process of probabilization.

With these three approaches to using symbols to represent the environment, we describe some schemes which have been used or proposed for storage of data on areas

Cell -- In this scheme a square or rectangular grid resembling a checkerboard is superimposed over the area of interest. Data within each square or rectangle may then be aggregated according to each type of variable. For example, if the variable is land use, the data recorded might be 35 percent type A, 20 percent type B, and 45 per cent type C. If the variable is population by age, the data might be 1-5 years (52 people), 6-8 years (24 people), etc. The Land Use and Natural Resource System (LUNR) developed by New York State is an example of an operational cell system. (Crowder, 1974)

Because the same geographical units are used for each variable, data in a cell system may be easily compared. This is an advantage for most analysis techniques. Suppose the spatial information system contained data about population density and land value in the form of two different variables--cell by cell--to suggest sites which would be inexpensive and disturb few people. One procedure for doing this might involve generation of a translucent map with the cells for each variable expressed in shades of gray. A darker shade might be used to indicate the less desirable (greater population or higher land value) condition of the cell. Then, by shining a light through the two maps, laid one on the other, cells in which development might be acceptable could be highlighted. This technique is called overlaying. (McHarg 1969)

Overlaying can also be done arithmetically. Rather than visual shades of gray, a "value" number between 1 and 10 is assigned to each of the two variables for each cell. A computer can be programmed to add these two numbers and produce a composite value for each cell. The lower the composite value, the more desirable the cell. (Dangermond and Antennucci, 1974)

There also are several disadvantages to the cell system. Any cell system implies a level of aggregation which must be a compromise among all the variables stored. A cell size must be chosen. For example, a square kilometer might be too large for some applications and data or too small for others. Another disadvantage is the loss of geographic specificity. Data may show, for example, that 10 percent of the soil in a cell is type A and that 10 percent of the cell area is in slope category X. These data together, however, cannot tell whether soil type A exists at specific points having an X slope--information that may be vital in some cases.

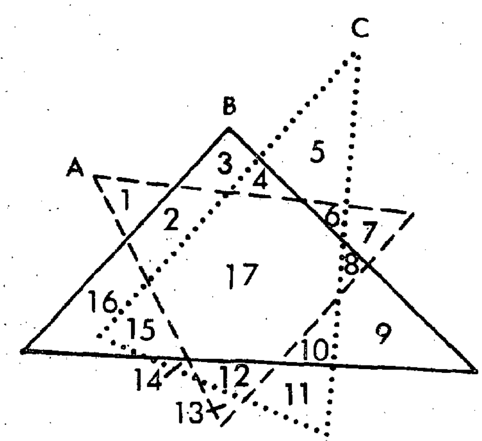
Once data are collected at one cell size, they cannot be easily disaggregated or converted. In addition, a real commitment is made when the checkerboard pattern is decided, since data are collected within cells and not across cells. Thus, any attempts to look at areas which cross cell boundaries may be thwarted. (Maercklein, 1968)

Polygon -- A polygon system depicts areas on the earth's surface as irregular geometric figures composed of three or more straight lines. For example, a vegetation map could be depicted as a set of figures having lines that enclose similar vegetation types. Such representations can be stored on a map as well as in the memory of a computer, by fixing the co-ordinates of each point and indicating that there are lines between the points. An operational example of a polygon system is the U.S. Department of the Interior's Bureau of Land Management and Bureau of Indian Affairs Natural Resource Information System. (Boeing Computer Services, 1972; Raytheon, 1973)

One advantage of a polygon is its geographic specificity. Although some precision is surrendered by limiting the system to straight lines when curves occur in the real situation, this loss is minimal and can be offset by using an increased number of shorter, straight line segments.

A major disadvantage of the polygon system is that data and the classification of data dictate the size, number, and configuration of the polygons. This disadvantage involves several implications--mostly bad. One example: If the question is asked of a polygon-based spatial information system, "Here is a pair of coordinates, what's the soil type?" the system must go through some real gymnastics to provide an answer. (A cell system, on the other hand, can't answer this question at all, but it can say what percentage of each soil type is close by.)

A more serious disadvantage becomes evident when a polygon system is asked to compare or overlay two or more variables (and keep in mind that the ability to do this is cited as a major reason to have a spatial information system). Overlaying several polygon maps or several polygon computer files to produce a composite is an extensive task. Even in the simple case of three variables (A, B & C) with a triangle figure for each, the sketch below demonstrates that an overlay process can yield 17 different figures.



The practicality of searching several overlaid polygon files for a suitable site for, say, an airport is, to understate the case, limited even with high speed computing equipment. One approach is to record the data with a polygon scheme but to process it into cells. This stores the data or features in a computer readable form as closely as possible to the real world situation--a strong advantage in the polygon technique. For manipulation and analysis, a new and separate file is created that has the polygon data assigned to grid cells. Such a combination technique provides flexibility in that if unanticipated resource management problems arise that require data in another form or grid cell size, the original polygon data is available for assignment to an appropriate analysis form. (Durfee, 1974)

Dot — Dot systems are relatively new. In a dot system a regular pattern of dots--either square or hexagonal--is imagined to lie over the geographic area. Then for each variable, such as soil type or land use, a single data value is recorded. This value might be the most predominant soil type or land use within the area surrounding the dot or it might simply be the condition at the dot.

The dot system resembles a cell system with two major differences: (1) the spacings between the dots is much smaller than the distances between centers of adjacent cells, and (2) only a single datum is recorded for each area surrounding the dot. An example of a dot system is the LANDSAT information developed on a routine basis by satellite. In this system, information based on electromagnetic radiation at several wavelengths is available for dots which have an implied area, called a picture element or pixel, of about one acre.

Another type of dot system is the not-yet-operational dot probability system being developed by the University of Louisville. In this system the datum stored at a dot is the condition which is precisely at that dot. There is the implication that the condition at the dot is representative of the condition of the area surrounding the dot, but there are no guarantees. Dot systems have the easy referencing and overlay capabilities of cell systems, the geographic specificity of polygon systems, and a rather profound internal storage advantage over either cell or polygon systems. The disadvantage is that they are based on the idea of homogeniety of the area surrounding the dot, as with the LANDSAT system, or on probabilistic measures as with the Louisville system.

So what paradigm should one use to represent the real world in a few symbols in a computer? Point and line data are not too much of a problem because they do not account for very much of the data base and the issue of level of detail is not a factor. The data are either recorded or not. But if the zero and one dimensional data are easy to deal with, the representation of two dimensional phenomena is a difficult design decision.

Other Storage Considerations:

The storage of symbols is subject to a great many other considerations which we touch lightly on here.

Area to be Covered — The total geographic area about which the system is to store data. A good system will be flexible enough to allow a variable to be stored in some geographical areas but not require that it be stored in all. For example, a system which makes provisions for the storage of tidal wetlands data over an expanse of desert is wasting something.

Level of Resolution — When information of the spatial type is stored in character form or in a computer memory, the issue of resolution becomes clearer than when information is stored in graphical or map form. For one thing, the matter of scale is involved. Resolution, then, is simply a measure of precision. In other words, where are the marks on the yard stick (or mile stick) that you lay down on the landscape? Are they every 1000 feet, every 50 feet? If the variable involved were "existence of surface water", would your system have the resolution to record a puddle, a swimming pool, a farm pond, or a large lake? Clearly, no system is going to record puddles and any system which can't see a large lake is in trouble.

A design decision regarding resolution is required early in the development of any system. The amount of data a system must handle increases by a factor of four when the degree of resolution becomes twice as fine, which shows that careful planning is required to develop a system that will be cost effective and responsive to needs.

Decisions regarding land require diverse and detailed information about persons, activities, events, and locations. Yet it is infeasible to record individual observations for every person, activity, event, or location in a state. It is infeasible on two grounds: (1) interrelationships among these observations are not well known, and (2) we do not have the ability to process that many observations. Consequently, it is necessary to abstract reality by aggregating persons to groups, activities to categories, events to time periods, and locations to areas. The level of aggregation becomes a key issue in designing a spatial information system. The data must be aggregated for efficient processing, yet must be detailed enough so as to investigate cause and effect relationships in order to estimate the consequences or impacts of decisions regarding land.

The key point is the tradeoff between collecting and manipulating large amounts of detailed data versus aggregating or abstracting map information into forms which can be incorporated into models which access the consequences of alternative courses of actions or decisions.

One capability that no operational spatial information system has been able to evidence so far is changeable levels of resolution for different variables and for different locations. If spatial information systems which deal mainly with the open spaces are ever to link up easily with the geographic base files in urban areas, this problem must be dealt with.

Data Volume -- By "multiplying" the area to be covered by the level of resolution, one obtains approximately the volume of data which are to be stored in the base. Every time a combination of storage scheme, area to be covered, and resolution is considered, a calculation of data volume should be made. The calculation can yield storage requirements so large as to send designers scrambling back to the drawing boards.

Organization of Symbol Data — It won't do just to drop all the numbers and characters into a basket. They must be placed in some order, whether in a filing cabinet, on some magnetic medium, or into the memory of a computer. Some order must be imposed for a variable on the data so they can be found when they are needed and can be compared with other data relating to the same geographic area. Even if the data volume is of a manageable size, poor organization can increase the bulk of space required to store the symbols. To give an everyday example, an office might allocate a single file drawer to files on other companies whose names begin with A, another with B, and so on, such that 26 drawers are allocated. When the files are put in the drawers, it will probably be discovered that some drawers, maybe Q and Z, are virtually empty while others, like A, are not large enough to hold the files. One can immediately think of different approaches to the problem--and that's just the sort of technical matter which must be considered no matter what the storage medium.

Georeferencing System -- Maps are flat and the earth's round--bumpy but round. Symbolic (number, letter, character) representation of the earth is neither flat nor round. Several coordinate systems can be used to reference geographic data, among them: State Plane Coordinate, Universal Transverse Mercator (UTM), and latitude/longitude. All except "latitude/longitude" suffer from the distortion of trying to make a spherical thing flat. "Latitude/longitude" suffers from not being based on ten (which people would like) or two (which computers would like) but on an awful combination of 360 and 60 which nobody likes except, perhaps, mariners of old.

A spatial information system must be able to accept data from various sources employing varying georeferencing schemes. A well designed spatial information system should have the capability to convert an array of different schemes into a referencing technique based on latitude/longitude. The system probably should also be capable of providing graphic information in a form corresponding to any of the more common georeferencing schemes. An automated system that is to provide information for analysis and management generally should not be based on a scheme designed primarily for maps. (Sinatra, et al, 1973; Tennessee Valley Authority, 1974) If a manual spatial information system is employed, probably a particular georeferencing scheme based on mapped data should be used.

Classification Schemes -- Some of the data for a spatial information system will be of the continuous sort—elevations, for example. But much of the data will have to be put into categories or classifications: land use data, soil types, and so on. There is no perfect classification scheme for natural phenomena. Even simple ones which give every indication of holding up, don't. For the simplest example, "Variable: living systems--Class A (plants); Class B (animals)" would seem to be a pretty basic, obvious scheme. As it turns out, it doesn't completely cover all cases. One finds classes such as Class C (both) and Class D (neither) added to complete it, and not very satisfactorily. Once the impossibility of a completely true classification scheme is recognized, we can talk about characteristics of a good classification scheme which will serve our needs. Such a scheme has the following properties:

- It is standard among those who use or might use it.
- It has rigorous specifications for each class.
- It is augmentable; new classes may be added.
- The distinctions between classes are based on the most fundamental properties of the variable.
- It is hierarchical in form. There are classes, sub-classes, sub-sub-classes.
- It is refinable. As more subtle information about classes is developed, more hierarchical levels may be added.
- It can be implemented. Specific data categories can be inventoried in a timely and cost effective way.
- It meets specific program data requirements; classes of data reflect analysis and management data needs.

It is almost always a mistake to start from scratch in the development of a classification scheme without careful examination of what others, who have faced similar problems, have done. There is an insidious danger inherent in many classification schemes which comes into play when the classified elements are compared with each other or with elements from another scheme. The danger, simply stated, is this: Numbers are frequently used as class identifiers: first degree burns, eighth tallest mountain, residence at 324 Applegate Road. Then, because a system of mathematical rules for manipulating numbers exists, someone may incorrectly add or multiply classification codes to get a "result." This error can occur in subtle ways. Overlaying a gray tone map is really an addition process which may be an inappropriate one.

Basically and briefly, there are four kinds of numerical classifications, each with its do's and don'ts regarding arithmetic operations. The first is nominal. Social Security Number 111-22-3333; Heavy Industry; Car 158. No arithmetic operations are valid for combining nominal classifications.

The second type of clasification (or scaling, as it is called) is ordinal. 1st, 2nd. A,B,C. An implicit order exists by virtue of the symbols. "A" is smaller than "B" is smaller than "C". 2nd is louder than 1st--but not (necessarily) twice as loud. One can't add or subtract such numbers and get meaningful results.

The third scaling type is called interval scaling. An example is the Fahrenheit temperature scale. If it is 20°F one evening and 80°F the next day, one may subtract and say 60°F warmer. But one may not say that it is four times warmer at 80°F. One may add and subtract interval scales but not multiply or divide them.

The fourth type of scaling is called ratio scaling. Here any normal arithmetic operations may be done. If one person is two feet tall and another six feet tall, then one may say the second is four feet taller than the first and the second is three times as tall as the first.

The moral of this discussion is: don't assume that it is valid to perform arithmetic operations on numbers which are used to represent objects, classifications, relationships, or idea. (Brandeis, 1973)

Degree of Automation -- This is a very difficult issue to come to grips with. Any spatial information system is predicated on the existence of a good set of base maps or photos. (Some good standards are USGS topographic maps and, where they exist, orthophotoquad sheets.) A system which operates solely with maps, photos, and visuals we call a manual spatial information system. If some of the data in a spatial information system expressed are in terms of symbols (numbers, letters, characters) and these symbols are stored in and processed by a digital computer, we have called the system an automated spatial information system.

Now the $64,000 question is: Do you want a digital computer as part of your system? Expressing spatial data in symbolic form is relatively new and not very easy. About the only thing which makes it feasible is the immense symbol manipulating capability that modern digital computers possess. (One example of this ability is arithmetic computation but there are others.) In short, symbolic representation is a poorer way to deal with graphic data than are maps unless you make a fairly large commitment in terms of data base size and symbol processing capability. It may be possible to start adding digital computer capability to a manual spatial information system on a small scale and work up gradually, but it will require careful consideration of specific objectives, not a general "once over lightly with a computer."

Many manual processes, such as accounting, matrix inversion, and parts inventory, have been automated in the last thirty years by having a digital computer emulate the manual process already in use. But there aren't any manual, symbol-based processes for manipulating spatial information because symbol-based spatial processes are too cumbersome compared with graphic processes, unless you have the capability of storing vast numbers of symbols (hundreds of millions) and manipulating them very quickly (millions of operations per second). Thus, automating the production of information for decision-making in our area of interest is not simply a matter of applying a computer to an existing system but rather devising completely new techniques. It's quite an undertaking. (Deutsch, 1966; Weller, 1971)

Equipment

Other reports in this series contain an extensive description of hardware (equipment) useful in spatial information systems. These reports include a technical discussion of: drafting equipment, automatic plotters, digitizers for automatic coordinate generation, computers (memory), storage devices, input and output units, mini-computers, and other components.

Here we wish only to make a few comments about equipment in general:

1. Buying equipment is one of the easier things to do (if you have the money) but one of the hardest things to live with if you make a mistake.

2. There has been noted a peculiar fascination on the part of some spatial information system developers with equipment—to the extent that other factors, more central to the success of the system, were ignored.

3. Don't buy any piece of hardware until you have seen it work in an

application similar to yours. Avoid like the plague untested equipment, regardless of promises.

4. Costs of electronic computing equipment and storage of symbol information is, unlike everything else, coming down in price.

5. Interconnections between items of equipment of different manufacturers is potentially troublesome. In a field such as this, where hybrid systems are likely, special attention must be paid to the interfaces between items.

6. The issue of fixing an item of equipment when it breaks is quite important. If one thing stops for three weeks, everything else may stop also.

7. The conversion of an automated system from one computer to another is a nightmare to be avoided. If you plan to use some central computing facility on a continuing basis, be sure there are plans to keep the machine for a few years.

8. Well-known computer manufacturers have been known to decide suddenly to go out of business with precious little regard for their customers. Any contract with a computer manufacturer, which entails support in terms of maintenance and programs, should be sufficient by itself and not based on the assumption that the manufacturer will continue to be around after the expiration of the contract.

The Procedures: For People, for Machines

For People -- Making a spatial information system useful to its users should be a process which takes place over a period of time. Fortunately, a spatial information system does not have to function like a moon rocket. For example, the base maps can be available for the user community well before some of the other products are. This means that there can be some leisure associated with developing the procedures which prescribe how the system is used.

As long as the remarks in this section are kept in mind, the precise lines along which requests and information flow can be allowed to evolve. For example, if some printed form seems to be desirable, it would probably be a good idea to produce a few of them for trial before ordering a long-term supply.

A few items in the procedures for people area should get attention early, in the design phase:

1. The question of confidentiality and access. Who may use the system? Who may get information from the system? Who may put information into it? Are some parts of the data base restricted from some users?

2. How are the services paid for? In an automated spatial information system which operates on a central computing facility there will at least be a charge for computer services. How the spatial information system group passes this charge along to the user (if it does) and how much additional is charged should be considered.

Only one thing is certain: costs will change and the charging scheme must be flexible over time.

3. As the system becomes loaded with requests for information, the question of priority for certain users will develop. How and by whom will conflicts be decided?

For Machines -- If one can afford to be somewhat relaxed about developing procedures for people to follow in using a spatial information system, the exact opposite is true when it comes to developing procedures for machines to follow. For example, computer programs (and other software) have got to be almost perfect the first time they are used in real situations or the system stands a real chance of going down the drain for lack of credibility.

In an automated spatial information system computer programmers will be involved. In the great majority of cases, computer programming for large projects is an abysmal failure. (It's bad for small projects, too, but there it can be redone until success is obtained.) Probably the best way to handle the computer programming is by contracting it out, specifying the entire package and going to a single contractor. The inputs (data and parameter types), the techniques for manipulating the inputs into outputs (products), and the outputs themselves must be carefully specified. Such a procedure limits flexibility during construction and puts a substantial load on the design staff to be precise; nonetheless, it is necessary.

The computer programmers for the project will not, with rare exception, have much of an overview of the objectives of the total effort. If they are good programmers, they have their minds full just writing and testing the instructions which will make the machine behave.

While computer programming is still an art, there are some definite procedures which should be followed to raise the success rate. First, a large number of small programs, called modules, should be written and linked together rather than having a few larger programs. Secondly, every program should be carefully documented so that, if the original programmer leaves, someone else will be able to understand the program. A new concept in computer program construction, called the chief programmer team, has been successfully employed on some large projects. Some investigation into this approach as well as the technique of structured programming is worthwhile prior to undertaking any large programming project.

Finally, there is the subject of testing. In hopes that a very short statement on a vital subject will be remembered <u>in toto</u>, we state: Any automated spatial information system developers who <u>don't</u> take testing seriously enough to institute an independent, intensive testing program will live with a buggy system for years--if the system survives.

References

Arms, S., 1968; Computer Mapping in Selected Geographic Information Systems; Papers from the 6th Annual Conference of the Urban and Regional Information Systems Assoc., Kent State Univ., Kent, Ohio.
ABSTRACT: Several computer mapping systems are described for geographic information. The description is most comprehensive about Canada's Geo-Information System developed by Tomlinson. He compares Tomlinson's system to selected other similar systems such as the DIME system developed by the New Haven Census Use Study, the Street Address Conversion System (SACS) developed by Robert B. Dial, the Parcel Inventory system, such as the Metropolitan Data Center Project system and the Map/Model system (CRAG) from the University of Oregon.

Barraclough, R. E., 1964; Geographic Aspects of Information Retrieval; Part of Urban Information and Policy Decisions, 2nd Annual Conference on Urban Planning Information Systems and Programs.
ABSTRACT: Two alternative methods of tagging information to define its geographic location are discussed: the name method and the location method. The name method is much more used today than it deserves. It is sustained by the weight of data so identified rather than by any intrinsic merit. The location method almost certainly will replace the name method as the principal means of geographic identification.

Barrett, J. C., 1969; Structuring Regional Data; Papers from the 7th Annual Conference of the Urban and Regional Information Systems Association, Kent State Univ., Kent, Ohio.
ABSTRACT: The operational files in a city or a region will, if structured correctly, produce a base for an information system that will be responsive to the needs of an administrator. The role of the Metropolitan Washington Council of Governments in helping to structure various regional files to yield information needed in regional planning is described.

Boeing Computer Services, 1972; Natural Resource Information System for BIA and BLM; Demonstration of System Features and Capabilities, Boeing Computer Services, Seattle, Washington
ABSTRACT: A computer-based system is described which stores, processes and displays data of maximum usefulness to land management decisionmaking. Problem statements with typical solutions are presented in the area of range management

Brady, E. L.; Branscomb, L. M., 1972, Information for a Changing Society; Science, 175, (3), 961 - 966.
ABSTRACT: A summary is presented of the contents of a report prepared under the auspices of the OECD entitled, information for a changing society. The report examines the uses and needs for scientific and technological information throughout society, and considers the relations among such information and other kinds of information.

Brandes, C. E., 1973; Methods of Synthesis for Ecological Planning; A Master's Thesis in Regional Planning, Department of Landscape Architecture and Regional Planning, University of Pennsylvania, Philadelphia.

Bricker, G. B., 1971; Closing the Loop in Environmental Design, Part of Kennedy, M. (Ed.), Proceedings of the Kentucky Workshop on Computer Applications to Environmental Design, University of Kentucky, Lexington, Kentucky.
ABSTRACT: Developments in high-technology environmental design are discussed. Environmental design is traditionally a noncybernetic discipline, primarily because structures are traditionally thoughtof as static. That view is invalid: structures serve human purposes continuously and should be monitored and adjusted accordingly. This requires methods for establishing feedback between the design of the environment and its performance. Designers of high-technology environments, where noncybernetic levels of performance cannot be tolerated, use information systems to advantage in closing the feedback loop. The principles of such information systems can be applied to the design of information systems for low technology environments. Examples of information systems in support of space exploration and in support of operations on the north slope of Alaska are analyzed. Some general principles concerning information and environmental design are drawn from these examples. The most interesting conclusion is this: if the designer is outside the feedback loop, he is merely a possible perturbation.

Catanese, A. J., 1968; Automation in Planning: Some Perspectives of United States Experience; Plan: Journal of the Town Planning Institute of Canada, 9 (1), 24 - 31.
ABSTRACT: Only a few parts, or sub-processes, of planning can be automated and these are the regularized and analytical aspects of planning. Subprocesses should be automated when: the data base of the planning information system is too large to allow for manual techniques; and the analytical system that has been developed is too complex, and the variables so numerous that manual techniques are inadequate. Two specialized applications of automation are discussed: information systems and analytical systems. The problems of automation in planning which include organization, personnel, financing, and technology, are briefly reviewed.

Christensen, R. E., 1971; The Update and Maintenance of Geographic Base Files Including Man-Machine Graphic Approach, Urban Data Center, University of Washington, Seattle, Washington.
ABSTRACT: The changes that affect an urban area geographic base file and the methodology for identifying these changes are discussed. The incorporation of these changes into a geographic base file are considered and the update and maintenance systems designs are described. Technical information is provided concerning the design, capabilities, and limitations of a prototype updating system. Chapters are devoted to discussions and descriptions of: the elements of a street segment geographic base file; changes affecting an urban area base file and their identification; the update and maintenance of a base file; and a prototype, interactive/graphic/real-time updating system.

Clark, W. L., 1967; Urban Geocoding Systems and Their Utility, In: Thresholds of Planning Information Systems, American Society of Planning Officials, Chicago, Illinois (p. 57 - 59).
ABSTRACT: An urban geocoding system is a computer-assisted technique to retrieve spatially oriented data without preconceived commitment to areal unit definition. The utility of the system for spatial data collection and retrieval is limitless since the system is separated into several components in such a way that it can be entered at any point.

Colorado School of Mines, 1971; Colorado Land Use and Environmental Resource Inventory (CLARI): Final Report; The Basic Engineering Department, Golden, Colorado.
ABSTRACT: A description of the Colorado land use and Environmental resource inventory (CLARI) is provided.

Craven, C. W., Jr. etal, 1973; Regional Environmental Systems Analysis: Progress Report June 15, 1971 - June 15, 1972, ORNL-NSF-EP-12, A review of the research of the Regional Environmental Systems Analysis (RESA) group of the ORNL-NSF Environmental Program.
ABSTRACT: The purpose of the research is to develop and communicate to the planning and management community a scientific basis for forecasting the environmental impacts of public and private decisions (such as land use) in order to improve environmental resource management. The research strategy is to develop and validate a hierarchy of empirical models representing the relevant economic, physical, ecologic, and social processes at each of several regional levels and to study and test their implementation processes by direct interaction with planners, decision makers, and the interested public. The work is grouped into five areas:

1. Socioeconomic analysis to develop systematic procedures for forecasting changes in population and employment for a geographic region consisting of an urban core with substantial rural fringes.

2. Land-Use analysis to develop the basis for spatially allocating regional population and employment forecasts and determining related land utilization.

3. Ecological analysis to develop measures of the burden placed on the ecological system by spatially distributed activities, and the resulting impact on the environmental quality of the system.

4. Sociopolitical analysis to describe the impact of the environmental condition of society, society's perception of that impact, and subsequent management strategies and political processes of response.

5. Implementation and Communications research to develop effective means of transferring the information and analysis techniques to the decision-making community and to test the usefulness of the work as applied to current problems.

The principal regional focus and testing ground for the work is a 6500 square mile region in the East Tennessee Valley surrounding Knoxville, Tennessee, known as the East Tennessee Development District. However, the methodology is designed to be applicable to other regions.

Crowder, Robert, 1974; LUNR, Land Use and Natural Resource Inventory of New York: What is it and How is it used; Office of Planning Services, Albany, New York.

ABSTRACT: A description of the New York LUNR information system is presented. Major applications of the system illustrate examples of state, regional and local requirements for land and resource data.

Dangermond, J., and Antennucci, J., 1974; Maryland Automated Geographic Information System (MAGI); Maryland Dept. of State Planning, Baltimore, Maryland.

ABSTRACT: A description of MAGI system and its capabilities for analysis are provided. In addition, a critical analysis and limitations of the system are shown.

Dangermond, J., 1973; Technical Alternatives for Geographical Information Systems at the State/Regional Level; Presented at the Urban and Regional Information Systems Association Annual Meeting.

ABSTRACT: Numerous technical options for utilizing land and natural resource data th the state and regional levels are presented. Major technical problems found in the development and operation of information system at this scale are discussed.

Department of Regional Economic Expansion, 1970; The Canada Land Inventory -- Objectives, Scope and Organization, 2nd Edition, Queen's Printer for Canada, Ottawa, Canada.
ABSTRACT: The inventory provides information essential to land development planning at the municipal, provincial and federal levels. Land is classified as to its capabilities and a firm estimate is made of the extent and location of each land class. Land is classified according to: physical capability for use in agriculture, forestry, recreation, and wildlife; and its present use. Information is also presented on soil capabilities, freshwater capability for sport fish, socio-economic classification of land, and agro-climatic classification.

Deutsch, K. W., 1966; On Theories, Taxonomies, and Models as Communication Codes for Organizing Information; Behavior Science, 1 - 17, February.
ABSTRACT: Better schemes for organizing the available information are critically needed if the full potential of electronic data storage and retrieval is to be utilized. Some of the main considerations relevant for developing better methods for the evaluation of such schemes are considered from the viewpoint of communication in both its technical and social aspects. Examples are given from current theories of nationalism, power, and value.

Durfee, R. C., 1974; ORRMIS: Oak Ridge Regional Modeling Information System, Part I, ORNL-NSF-EP-73, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
ABSTRACT: A geographically oriented information system is being developed by the Regional Environmental Systems Analysis Program at Oak Ridge National Laboratory (ORNL). The system is being designed to operate either as a stand-alone inquiry-retrieval system or as a communications supervisor for use with simulation models. The primary purpose of ORRMIS is to provide the data management capability for analysis models which forecast the spatial distribution and ecological effects of activities within a geographical region. The geographic orientation of the system may, however, be replaced with a more general adjacency relationship thereby extending its use to non-geographic models.

Environmental Systems Research Institute, 1974; Information Needs for New Castle County,Area Wide Water Quality Management Planning Program, Redlands, California.
ABSTRACT: Information, problems, and solutions relating to the New Castle County, Delaware, Area Wide Water Quality Management Planning Program sponsored by the U.S. Environmental Protection Agency under Section 208 of Public Law 92-500 are presented.

The report grew from a need to better understand data and information requirements necessary for anticipated problems and decisions that will occur not only during the two year planning program effort, but during ongoing implementation and management of the plans originating from this program.

The body of the report presents four major categories of investigation:

I. The Data Requirements Necessary to Support Program Decision Making
II. The Data Sources Available within the County
III. A Design for an Efficient and Simple Information System
IV. An Outline for Implementation of the System.

The techniques for information handling and analysis described in the report will not answer all of the information needs of the agency. It is felt, however, that the systems presented herein will be more than sufficient for the majority of information needs. It is furthermore felt that the simplicity of the information structure provides for a completely flexible approach to inclusion of data elements, data processing, and analysis.

This system was initially designed for area wide water quality management during the initial planning stages (the next 2 years), as well as the continuing management stage. In addition, its future as a tool for many of the city, county and state agencies involved in environmental and land use issues can be extensive. Similar systems developed for the State of Maryland, the County of Santa Barbara, and the City of Yokohama, Japan, have proven to be widely used for a variety of applications.

Farman, M.; Nivergelt, J. (Eds.), 1969; Pertinent Concepts in Computer Graphics; Proceedings of the 2nd University of Illinois Conference on Computer Graphics, University of Illinois Press, Urbana, Illinois
ABSTRACT: A series of papers is presented on a broad class of interests in the area of computer graphics, ranging from devices through techniques (both hardware and software), systems, applications and underlying principles.

Frye, J. C., 1967; Geological Information for Managing the Environment, Illinois Geological Survey, Environmental Geology Notes 18.
ABSTRACT: The factual data needed from the earth sciences by the planner and administrator are discussed under 4 broad categories: data on the terrain; data for management and disposal of wastes; data for water resource development and management; and data on the full range of usable rock and mineral materials and subsurface fluids. These 4 areas of application taken as an integrated whole can be termed environmental geology.

Haak, H. H., 1967; The Evolution of a Metropolitan Data System; Urban Affairs Quarterly, 3, 3 - 13.
ABSTRACT: Although a revolution has taken place in data processing, the development of metropolitan information or data systems requires an evolutionary approach. The San Diego approaches to data exchange systems is discussed and the legal aspects are considered.

Haak, H. H.; Bigger, W. R., 1966; A Coordinated Data System for Metropolitan San Diego; Public Affairs Research Institute, San Diego State College, San Diego, California.
ABSTRACT: A preliminary study was undertaken of the desirability and feasibility of a coordinated metropolitan data system employing electronic data processing equipment. The study involved: accumulation and analysis of materials produced as the result of other projects similar to that under consideration here; review of programs now in operation and proposed by the city, the county, the schools, and the state of California, together with a preliminary analysis of overlapping data needs; and, discussion with a sample of persons in government and business concerning the desirability and feasibility of a coordinated data system in the San Diego community. The problems which must be faced are discussed in detail and include: legal problems of sharing information; systems requirements; and determination of the organization and scope of the system.

Hanold, J. L., 1972; Mapping and Digital Information Systems; Proceedings of the 38th Annual Meeting, American Society of Photogrammetry, Washington, D. C.
ABSTRACT: A digital information system for any organization with property dispersed over a significant area requires a geographic tie. This implies a need for a map base and the better the maps, the better the base. However, a system based on a rather poor set of maps can be amazingly effective provided a suitable geographic data base or matrix is used and the files are properly conceived. Traditionally, digital information systems are built in sequential steps--first, the base system; then the addition of plant inventory, land parcels, etc.; and finally the conversion of this data along with data from traditional files to digital form. Aside from the greater expense and lost time, this sequential approach ignores one of the prime capabilities of the system at a time when this capability can be most useful.

Holden, A., 1968; Engineering Soil Mapping from Airphotos, Photogrammetria, 23 (6), 185 - 199.
ABSTRACT: With the necessity of producing trained staff in the shortest possible time, methods of data storage have become vital. In Rhodesia an index system, built up from experience, was prepared and is available to the interpreter. By referring to a simple form of card index system on which are recorded similar geological, topographical, climatical and drainage patterns, he can obtain the necessary information to enable him to undertake airphoto evaluation of an area even though he may never have had previous experience with the type of country or geology in which his assignment falls. Samples of the index card system and an engineering soils map prepared using the method outlined are presented.

Hoos, I. R., 1971; Information Systems and Public Planning; Management Science, 17 (10), B-658 - B-671.
ABSTRACT: The research focus of the work is on information systems as entities in themselves and as components of a larger systems design. After analyzing the 3 discretely defined but operationally joined concepts, information, system, and the information system, 4 assumptions underlying the general acceptance of the information system as a management tool are examined: that more information leads to better plans or decisions; that more and faster-moving information necessarily enhances "efficiency" of operation; that great "efficiency" is identical with better public service; and that information systems are best conceived, designed, and controlled by "information experts," whose talents are movable and ubiquitous. Information systems in public welfare, criminal justice, and land use are reviewed as cases in point. While there is no gainsaying the fact that in each area a body of organized information is essential to systematic analysis and planning, there exists considerable confusion between quantity and quality, between the necessary and the busy. So far, there is a lack of clarification not only as to the proper constitution of the information system but also about the qualifications of the "experts" designing them. Unfortunate as these matters are in raising the costs and lowering the benefits, they have ominous implications when viewed in the light of the man-fronted encroachments by computerized information systems on individuals' right to privacy. The data bank and the dossier may be rationalized as means to efficiency, but they cannot be reconciled with democratic process and freedom from cradle-to-grave surveillance.

Horwood, E. M., 1967; State of the Art of Planning Information Systems; Part of Thresholds of Planning Information Systems, American Society of Planning Officials, Chicago, Illinois.
ABSTRACT: A definition of an urban and regional information system is presented and six systems are identified and defined: geocoding system; query system; automated number graphic display system; plan test system; planning operations system; and capital improvements and work scheduling system. The planning fraternity is not yet capable of developing information systems and the data base itself. The special purpose information systems that are being developed are not capable of addressing themselves to the across-the-board requirements of the typical planning operation.

Kusler, J. A., etal, 1975; Data Needs and Data Gathering for Areas of Critical Environmental Concern, Part I, II, & III; Institute for Environmental Studies, University of Wisconsin, Madison, Wisconsin.
ABSTRACT: Results from a study addressing data needs and data gathering approaches for the definition and management of critical environmental areas are presented. Part I includes the study conclusions and recommendations; Part II includes selected papers from state resource management program personnel; and Part III is an executive summary.

Laboratory for Computer Graphics and Spatial Analysis, 1970; Users Reference Manual for Synagraphic Computer Mapping "Symap"; Graduate School of Design, Harvard University, Cambridge, Massachusetts.
ABSTRACT: A detailed description of Symap and its software is presented.

Land's Directorate, Environment Canada, 1973; Canada Geographic Information System Overview; Information Canada, Ottawa, Canada.
ABSTRACT: A description of the Canadian Geographic Information System (CGIS) is presented along with a brief history of its development.

Leyland, G., 1969; Cost-Benefit Analysis of Urban Information Systems; Papers from the 7th Annual Conference of the Urban and Regional Information Systems Association, Kent State University, Kent, Ohio.
ABSTRACT: Some of the basic questions about the worth of an information system in a community are explored. Although the cost/benefit analysis of information systems alternatives are put into highly specific terms, many undocumented assumptions and subjective appraisals are hidden in the analysis. Even so, the detailed quantitative analysis highlights the most important aspects of community information systems and provides a framework in which to consider the system alternatives.

Lockheed Missiles and Space Co., 1965; California Statewide Information System Study, Final Report, Lockheed Missiles and Space Co., Sunnyvale, California.

ABSTRACT: Present and proposed information-handling activities and requirements of the State and local governments as related to the State were analyzed. A preliminary conceptual design of a statewide information system was developed to meet these needs and a plan was prepared for the development and implementation of such a system.

Lundberg, F. J., 1967; Urban Information Systems and Data Banks: Better Prospects with an Environmental Model; In: Thresholds of Planning Information Systems, American Society of Planning Officials, Chicago, Illinois (p. 63 - 69).

ABSTRACT: Many communities have enthusiastically created an information system and data bank only to find that inadequate information for planning purposes was produced. The reasons for the failure of these systems are examined and a model is proposed for almost all public and private elements engaged in community improvement.

Maercklein, L. A., 1968; The Development of a Statewide Mapping Program and Projection-Grid System; Program Analysis Bureau, Planning Division, New York State Department of Transportation, Albany, New York.

ABSTRACT: A discussion is presented on the demands for a coordinate system to meet the need for geographic control of data when computer equipment is used. The unique problems of New York State in establishing a statewide coordinate system are outlined and the new mapping program which utilizes this coordinate system is described.

McHarg, I. L., 1969; Design with Nature; The Natural History Press, Garden City, New York.

ABSTRACT: The recognition that man's life is bound up with the forces of nature, and that man must, therefore, work with nature rather than attempt to conquer it, must be applied to every aspect of planning and handling of the environment. The destructive role of man and his thoughtless application of modern technology are described and through extensive concrete examples the new awareness of ecology is applied to produce constructive environmental design. Emphasis is placed on the necessity for human cooperation with nature. Design must evolve from the potentialities and the restrictive conditions nature offers.

Meltz, S. J., 1971; Geonatural Resource Development; a Working Paper Presenting Notions and Consideration Oriented toward Achieving Positive Action Solutions to Environmental Problems; Georgia Center for Continuing Education, University of Geologia, Athens, Georgia.

ABSTRACT: A discussion is presented on certain ideas that can be synthesized into a philosophical foundation from which realistic and workable solutions to environmental problems can be formulated. The ideas discussed focus upon the concept of balance. This concept is oriented toward establishing an equilibrium between the needs of society and a quality environment for man. The topics discussed include: the practical aspects of the concept of balance; meaningful communication; a practical meaning of the term environmental; the failure of traditional land-use planning approaches; levels of planning decisions; environmental resource planning decision; requirements for public affairs decision making; and comprehensive environmental education programs.

Meyers, C. R., Jr.; Durfee, R. C.; and Tucker, T. C., 1974; Computer Augmentation of Soil Survey: Interpretation for Regional Planning Applications; ORNL-NSF-EP-67, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

ABSTRACT: Interpreted soil data are a needed ingredient in all levels of the planning process; however, with (1) the time delay between soil scientists' field work and published soil maps and (2) the changing variety of soil interpretations needed by planners, much of the potential usefulness is lost. A joint working agreement between the Oak Ridge National Laboratory Regional Environmental Systems Analysis Program, the Computer Sciences Division, and the State of Tennessee Soil Conservation Service has resulted in the development of a computer information system which accepts raw field data, thereby allowing soil interpretations to be made and mapped quickly. Steps to implement the system include: (1) generation of computer-drawn field sheet grid overlays, (2) delineation of gridded soil boundaries by soil scientists, (3) digitization of these soil boundaries, (4) production and editing of quick-look soil maps, (5) computer generation of various scale soil maps, and (6) soil interpretation and mapping. Utilizing such a system has allowed decisions to be made easily concerning definition of soil boundaries, soil interpretations, etc. These interpretation maps may then be integrated into the planning process by the regional planner. Implementation of this system has produced solutions to many problems of both soil scientists and planners, thus closing the gap between the two sciences.

Parker, J. L., 1971; Information Retrieval with Large-Scale Geographic Data Bases; Department of Computer Science, University of British Columbia, Vancouver, B. C., Canada.

ABSTRACT: There has been growing interest in dealing with large-scale geographic data bases because of the growing capacities of computer systems and because of the increasing interest in environmental and social systems. The problems associated with these data bases from data acquisition to simulators and information retrieval are outlined and an overall approach to the problem using polygons, point data, and common coordinate systems is developed. A method of grid independent data observation is explained. A variety of specific problems of file management and information handling which arise in large-scale information systems dependent on data of a two-dimensional structure, as opposed to data of a linear or hierarchical structure is explored.

Robinson, A. H., and R. D. Sale, 1969; Elements of Cartography; John Wiley & Sons, Inc., New York, New York.
ABSTRACT: A broad discussion of the art and science of cartography and the major cartographic elements, such as map compilation, symbolizing and processing data, map projections, and map reproduction are presented. In addition, geographical tables and map projection formulas are included.

Shawn, R. B., 1968; Macro Design of Regional Information Systems; Papers from the 6th Annual Conference of the Urban and Regional Information Systems Association, Kent State University, Kent, Ohio.
ABSTRACT: Regional information systems are currently oriented to a single problem area (e.g., transportation). It's now necessary to build general regional systems. The first step is the development of a system "Macro Design." This design is a careful determination of: information requirements; information availability; best use of existing systems; how to best supplement existing systems with new equipment.

Shelton, R. L., 1968; Air Photo Interpretation and Computer Graphics for Land-Use and Natural Resources Inventory; Papers from the 34th Annual Meeting of the American Society of Photogrammetry, 198 - 204.
ABSTRACT: For a state-wide land use and natural resources inventory, a classification of 135 land and water uses was designed appropriate jointly to air photo interpretation techniques, to computer analysis and display, and to a broad range of needs for information for resource planning and management A geographic referencing system based on 1 km2 UTM grid cells is used to locate information interpreted from 1:24,000 aerial photographs and mapped on topographic map overlays. The cells then serve as the basic unit for computer graphic display utilizing standard line printers. The techniques may be extended to even larger areas and to various remote sensor operations.

Siegal, R. A., 1966; A Program Approach to Information Systems; Proceedings of the 4th Annual Conference of Urban Planning Information Systems and Programs, University of California, Berkeley, California.
ABSTRACT: There is a need for an information system that will allow public management to make better decisions. Information system specialists might profit from working with management control systems devised by other disciplines. Information system specialists could make a great contribution by making these other systems operational. The planning, programming, and budgeting system would be of great usefulness to information system specialists by offering a framework to guide the collection and classification of data.

Sinatra, J. B., etal, 1973; A Land Classification Method for Land Use Planning; Land Use Analysis Laboratory, Iowa State University, Ames, Iowa.
ABSTRACT: A method of land classification is presented and illustrated using the Iowa Upper Mississippi Valley region. Operational definitions are given along with a review and discussion of principal issues dealing with land classification and spatial data handling.

Snow, C. P., 1955; Science and Government; Lecture given at Harvard University, Cambridge, Massachusetts.

Teitz, M., 1966; Land Use Data Collection Systems: Some Problems of Unification; Papers of the Regional Science Association 17, Philadelphia, Pennsylvania, University of Pennsylvania Regional Science Association.
ABSTRACT: Strategies that data collection agencies might take and the variables relevant to their decisions are considered. The requirements of a unified data collection system are outlined and the cost implications are considered. To do this a formal analysis is employed which allows the isolation of those questions necessary to rational decision making about data and its utilization.

Tennesse Valley Authority, 1974; Land Analysis Systems; Presented to the Conference on the TVA Experience at the International Institute for Applied Systems Analysis, Schloss Luxenburg, Austria.
ABSTRACT: Since its inception in 1933, the Tennessee Valley Authority (TVA) has maintained an interdisciplinary approach in resource planning and development. Today, modern system techniques coupled with a rich legacy of historical data and Valley-wide mapping systems, aid TVA in land planning and development, land management decision-making, and environmental impact assessment.

This paper outlines land analysis systems being used and developed by the Division of Forestry, Fisheries, and Wildlife Development. These systems all use spatially located data and are described as follows:

1. The Valley-wide Forest and Wildland Monitoring System functions as an "early warning" of potential conflicts between land development and natural systems. It consists of locational data for key facilities and important resources and amenities which should be preserved or approached with care.

2. The Forest Resource Analysis System enables the characterization and modeling of timber growth, forest industry opportunities, and ecological succession.

3. The Bioterrain Analysis System manages large geographical data sets for land capability analysis and simulation.

4. The Land Management Decision System is a decision-making process designed for use on large land holdings where site-specific, intensive management is coordinated with a variety of resource output objectives.

5. The Regional Natural Systems submodel predicts the impact of land development on the natural systems of the region.

Land analysis systems of the future will emphasize analyses that will alert the planner to probable second and third order effects that might not otherwise be anticipated. Recent developments in computer hardware and software and increasing systems awareness by natural scientists should increase the utilization of land analysis systems in the land planning, impact assessment, and management decision-making processes.

Tomlinson, R. F., 1967; An Introduction to the Geo-Information System of the Canada Land Inventory; Canada Department of Forestry and Rural Development, Ottawa, Canada.
ABSTRACT: The Canada Land Inventory Geographic Information System has several new concepts and techniques. The over-riding consideration, however, is the creation of a data bank containing not only descriptive information, but a compact, useful form of the related boundary information. The system can be of inestimable value to a country such as Canada in providing a sound basis on which decisions on planning and development of resources can be made particularly in the context of regional rehabilitation and project planning. The system is basic to a geographical understanding of the country and has application in any nation where the developing economy is concerned with the natural resources.

Voelker, A. H.; and Meyers, C. R., Jr.; 1972; Computer Display in Spatial Modeling, ORNL-NSF-EP-25, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

ABSTRACT: A discussion is presented on the role of computer display in a hierarchy of spatial data activities which range from simple data transformations to sophisticated simulation models. Three general sets of spatial data problems are considered: (1) processing data for input to an application in which the data are synthesized; generation of maps, graphs, and overlay plots; and (3) simulating model output, histograms, spatial plots, three-dimensional perspectives, etc. The computer should not be used to duplicate traditional cartographc maps; rather, computer display should be built around the strengths of computers: flexibility, speed, and the dynamic nature of man/machine interactions.

Weller, B. S., 1971; Paradigms for the Development of Standardized Data Bases; Presented at the Annual Conference of the American Institute of Planners, October 24 - 28, San Francisco, California.

ABSTRACT: The Wichita Falls, Texas Municipal Information System Consortius recognized that standards and standardization procedures are intrinsic to the conceptualization, design, development, and implementation of an integrated municipal information system. Consequently, standardization was selected as one of the themes of the Conceptualization Phase, and a guidelines essay was prepared on the topic. This paper overviews and extends the essay as follows: First, the suggested phases of data base development--specification, acquisition, processing, dissemination and application of data elements, items and formats--are discussed. Second, the phases are related on a pairwise basis to establish a data specification-to-data application, iterative, chain of events. The sections on phases and pairwise relationships are then used to provide a framework for structuring several standards-senstive data base development paradigms.

Wischmeier, W. H.; Smith, D. D., 1968; Rainfall - Erosion Losses from Cropland East of the Rocky Mountains Guide for Selection of Practices for Soil and Water Conservation; U.S. Government Printing Office, Washington, D. C.

ABSTRACT: The soil-loss prediction procedure presented here provides guidelines to help select the soil and water control practices best suited to the needs of each farm. The technique combines all pertinent research information to provide design data for conservation plans. The empirical soil-loss equation underlying this technique is applicable in any location where numerical values of the equation's factors are known or can be determined.

Other Documents of Interest

Title & Content	Availability
1. Primer: Critical Areas and Information/Data Handling, January 1976. General introduction and overview of this subject	Out of print
2. Critical Areas: A Guidebook for State and Local Governments, April 1977. The Guidebook considers the derivation of critical areas programs from the American Law Institute (ALI) Model Land Development Code and the examples of a number of States which have developed programs. It outlines the basic elements of a critical areas program and discusses the considerations and some of the alternatives involved in each. In this manner the State program manager, legislator, local official and concerned public are presented an overview of all the factors involved in setting up and operating a critical areas program, the sequence of steps in initiating and adopting a critical areas program, and relevant experiences of other States.	Institute of Rational Design 220 West 42nd Street New York, New York 10036 Price: $5.00
3. Information/Data Handling: A Guidebook for Development of State Programs, July 1975. This Guidebook documents the elements of several information systems, and reviews the state-of-the-art of information systems that are now in the development stage.	Updated version available through the National Technical Information Service, P.O.Box 1553, Springfield, VA 22151
4. Introduction to Spatial Information Systems, April 1977. Information systems based on spatial or geographic locations are emerging as a tool for State, regional, and local governments. Such systems store energy, environmental, land use, demographic, natural resource and cultural feature information. Introduction to Spatial Information Systems provides a comprehensive look at such systems and the elements which comprise them. Part A develops the definition and understanding of such systems in a broad context; Part B enumerates and describes the uses to which such a system may be put; Part C describes procedures that a government might use to determine its sources, uses, and needs for spatial information and the capability to process it. The last three parts of the book are somewhat more technical: Part D discusses the products spatial information systems generate; Part E deals with issues of data-collecting, testing, updating, remote sensing, etc.; Part F is a discussion of the synthesis of data, hardware, money, software, personnel, and ideas to produce a spatial information system.	Urban Studies Center University of Louisville Gardencourt Alta Vista Road Louisville, Ky. 40205 Price: $5.00

5. Methods and Techniques (Technical Report A), July 1975. A technical analysis of the procedures used in the development of State critical areas programs, including a description of the key elements, issues and participants, a discussion of strategy considerations, and an outline of management tools.

   Out of print; materials contained in this report are included in the rewritten critical areas Guidebook

6. Case Studies (Technical Report B), July 1975. Summary analysis of the development and key elements of critical areas programs in Florida, Maine and Oregon.

   N.T.I.S., P.O.Box 1553
   Springfield, VA 22151
   Order Number: PB 263 603 AF
   Price: $5.50 (paper)
   $3.00 (microfiche)

7. Information/Data Handling Requirements for Selected State Resource Management Programs (Technical Report C), July 1975. A technical report analyzing characteristics of some important programs, including critical areas programs, and the types and availability of data and information needed for the effective implementation of the programs.

   N.T.I.S., P.O.Box 1553
   Springfield, VA 22151

8. Information Systems: Technical Description of Software and Hardware (Technical Report D), July 1975. A description and analysis of software considerations and special hardware and related processes for handling of spatial data, and a compendium of options, methods, and equipment that are either available or in practice.

   N.T.I.S., P.O.Box 1553
   Springfield, VA 22151
   Order Number: PB 263 804 AF
   Price: $6.75 (paper)
   $3.00 (microfiche)

9. Issue Papers (Technical Report E), July 1975. A series of discussions by leading experts on specific topics in the field. This format provides background on particular problems, including technical discussion and opinion by the authors.

   N.T.I.S., P.O.Box 1553
   Springfield, VA 22151

10. Geographic Data Encoding Issues, K. J. Dueker, Technical Series No. 43, 1975.

    Inst. of Urban & Regional Research
    N246 OH, Oakdale Campus
    University of Iowa
    Iowa City, IA 52242
    Price: $.50

11. Avoiding System Failure: Approaches to Integrity and Utility, Charles Guinn & Michael Kennedy, August 1976. A discussion of automated spatial information systems and their development by State governments is presented. It is not, however, dedicated to lofty or state-of-the-art considerations; rather it contains practical advice, based on "real world" experience, on how

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To keep such systems from resulting in failure. Avoiding System Failure: Approaches to Integrity and Utility deals with the financial, technical, political, and legal considerations during the stages of conception, design, construction, and operation. A must for anyone involved in the arduous task of developing a computerized geographic information system on almost any scale.

12. State Land Use Planning Process Issues: Geographic Information Systems Implications, K. J. Dueker & R. Talcott, Technical Services No. 94, November 1975.
Inst. of Urban & Regional Research
Address same as above.
Price: $1.00

13. "Geographic Data Structures: Alternatives for Geographic Information Systems," K. Dueker, July 1976. In: Computer Graphics Proceedings of the Third Annual Conference on Computer Graphics, Interactive Techniques and Image Processing--SIGGRAPH '76 (vol. 10, No. 2).
Association for Computing Machinery, Inc., P.O.Box 12105
Church Street Station
New York, NY 10249

14. Natural Resource Management Information Systems: A Guide to Design, John F. Tschanz & Alan S. Kennedy, January 1976. Spatial information/dada handling can be perceived to have a diversity of requirements, while at the same time have common structural characteristics. This Guidebook outlines the general structure of a resource management information system and a process for designing such a system.
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Division, Argonne National Lab.
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